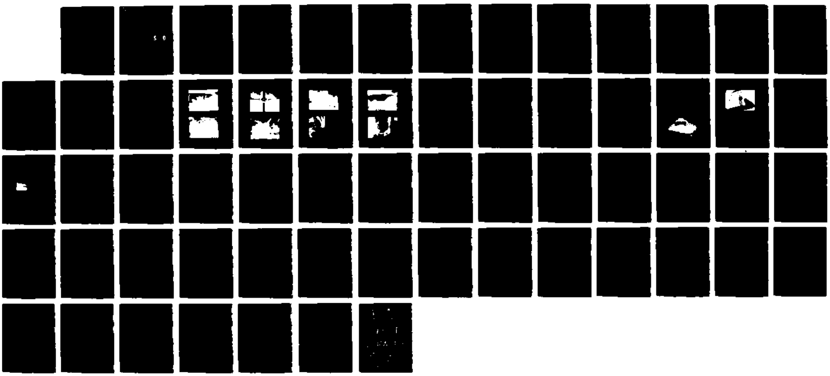
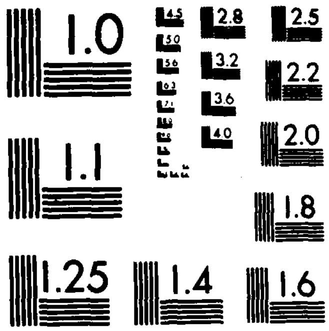
AD-A192 120 DEVELOPMENT OF OVERHEAD COVER FOR INDIVIDUAL FIGHTING POSITIONS(U) CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL D S MARSHALL FEB 88 1/1

UNCLASSIFIED CERL-TR-M-88/06 F/G 13/13 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

US Army Corps of Engineers
Construction Engineering Research Laboratory

USA-CERL TECHNICAL REPORT M-88/06
February 1988
Family of Battlefield Protective Shelters

2

Development of Overhead Cover for Individual Fighting Positions

by
Orange S. Marshall, Jr.

The U.S. Army Construction Engineering Research Laboratory (USA-CERL) has designed, developed, and tested an overhead cover (OHC) for individual fighting positions (IFP). The OHC-IFP is intended to protect soldiers against aerial-delivered and indirect-fire weapons on the battlefield while still allowing them an optimal fighting posture. The structure is lightweight and compact to ensure easy transportability into a theater of operations.

The OHC-IFP was designed using criteria developed by the Belvoir Research, Development and Engineering Center (BRDEC) in conjunction with USA-CERL. High strength-to-weight ratio materials were first evaluated to find a low-cost, easily manufactured product meeting the specifications. A prototype was built and tested, and the design was optimized. The revised prototype was load-tested and then turned over to an independent test agency for field construction and assessment.

USA-CERL's structure meets the requirements for overhead cover support as originally specified in 1984. Weight, packaging, temperature, and load support all fall within the ranges listed in the criteria. In addition, the customer test showed that the USA-CERL OHC-IFP allows firing from under cover and meets the height requirement. Based on these findings, it is recommended that the USA-CERL design be refined and demonstrated in the field; the final product should be listed as standard equipment in the Army supply system.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A192 128

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704 0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S): USA-CERL TR M-88/06	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION: U.S. Army Construction Engr Research Laboratory; 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code): P. O. Box 4005 Champaign, IL 61820-1305	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING/SPONSORING ORGANIZATION: Office of the Chief of Engr; 8b OFFICE SYMBOL (If applicable): DAEN-ZCM	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code): The Pentagon Washington, DC 20310-2600	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
4A16273	AT41	E	043

11 TITLE (Include Security Classification)
Development of Overhead Cover for Individual Fighting Positions (Unclassified)

12 PERSONAL AUTHOR(S)
Marshall, Orange S.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM ______ TO ______	February 1988	57

16 SUPPLEMENTARY NOTATION
Copies are available from the National Technical Information Service
Springfield, VA 22161

17 COSATI CODES

FIELD	GROUP	SUB-GROUP
15	03	

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Overhead Cover for Individual Fighting Positions
foxholes
coverings fortifications

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The U. S. Army Construction Engineering Research Laboratory (USA-CERL) has designed, developed, and tested an overhead cover (OHC) for individual fighting positions (IFP). The OHC-IFP is intended to protect soldiers against aerial-delivered and indirect-fire weapons on the battlefield while still allowing them an optimal fighting posture. The structure is lightweight and compact to ensure easy transportability into a theater of operations.

The OHC-IFP was designed using criteria developed by the Belvoir Research, Development and Engineering Center (BRDEC) in conjunction with USA-CERL. High strength-to-weight ratio materials were first evaluated to find a low-cost, easily manufactured product meeting the specifications. A prototype was built and tested, and the design was optimized. The revised prototype was load-tested and then turned over to an independent test agency for field construction and assessment.

(Cont'd)

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL: Dana Finney	22b TELEPHONE (Include Area Code): (217)352-6511(Ext. 389); 22c OFFICE SYMBOL: IMT-E

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

BLOCK 19 (Cont'd)

cont USA-CERL's structure meets the requirements for overhead cover support as originally specified in 1984. Weight, packaging, temperature, and load support all fall within the ranges listed in the criteria. In addition, the customer test showed that the USA-CERL OHC-IFP allows firing from under cover and meets the height requirement. Based on these findings, it is recommended that the USA-CERL design be refined and demonstrated in the field; the final product should be listed as standard equipment in the Army supply system.

FOREWORD

This research was conducted by the U. S. Army Construction Engineering Research Laboratory (USA-CERL) for the Office of the Chief of Engineers (OCE). The work was conducted under Project 4A162731AT41, "Military Facilities Engineering Technology"; Task E, "Military Engineering"; Work Unit 043, "Family of Battlefield Protective Shelters." The OCE Technical Monitor was Dr. Austin Owen, DAEN-ZCM.

The investigation was performed by the USA-CERL Engineering and Materials Division (EM). Dr. Robert Quattrone is Chief, USA-CERL-EM. Dana Finney, USA-CERL Information Management Office, was the technical editor.

COL N. C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

FIGURES

FIGURES (Cont'd)

TABLES

DEVELOPMENT OF OVERHEAD COVER FOR INDIVIDUAL FIGHTING POSITIONS

1 INTRODUCTION

Background

Construction of field fortifications has been a part of battle doctrine since the earliest efforts at defensive tactics in warfare. The purpose of these fortifications is to provide soldiers with protection from enemy fire while still allowing them to engage the enemy in combat. A standard method of protection has been the foxhole. Now, with the use of aerial-delivered fire and indirect-fire weapons on the battlefield, soldiers need to have overhead protection in addition to that afforded by the foxhole. To provide the necessary cover, a minimum of 18 in.* of compacted soil or 24 in. of loose soil is required. The overhead cover (OHC) support system must sustain these soil loads for as long as the fortification is occupied.

OHC support systems have been built successfully using logs, steel drainage culverts, ammunition boxes, and other materials soldiers have been able to locate near the battlefield; however, these materials are not always available and the structural integrity of some of the resulting OHC supports is very unsound. Some OHC support systems have been developed but, to date, the designs do not allow a soldier to fire from under cover or else are too heavy and cumbersome to transport by soldiers in the field. Thus, the Army supply system needs a standardized fortification to support OHC for individual fighting positions. To be successful, the OHC support must provide protection and concealment, but must not inhibit the soldier's fighting posture. Additional requirements are that the system incorporate high strength-to-weight ratio materials to meet production and specification requirements outlined in the *Operational and Organizational (O&O) Plan for the Overhead Cover for Individual Fighting Positions* (U. S. Army Training and Doctrine Command [TRADOC], 31 December 1984) and other criteria established by Belvoir Research, Development and Engineering Center (BRDEC) in conjunction with the U. S. Army Construction Engineering Research Laboratory (USA-CERL). Finally, the system must be lightweight and easily transported by soldiers on the battlefield.

Objective

The objective of this work is to design and develop a system for potential use in a theater of operations (T/O) to provide support for overhead soil cover over one- and two-man individual fighting positions (IFPs).

Approach

USA-CERL first evaluated high strength-to-weight ratio materials to determine those which could (1) meet the specifications and (2) be produced easily and inexpensively. Possible structural configurations were then evaluated, followed by a structural analysis of the members. From these analyses, a materials specification was

*Metric conversions are provided on p 28.

developed and a prototype built. Fastening mechanisms were evaluated for ease of operation and the design was optimized. The prototype was rebuilt to incorporate these changes and the structure was load-tested. Thirty prototypes were constructed and assessed for the Army by an independent test agency.

Mode of Technology Transfer

The OHC-IFP system developed in this study will be demonstrated in the field and included in a series of user tests to be conducted by the U. S. Army Development and Employment Agency (ADEA), 9th Infantry Division. From the results of this test, a joint working group representing the material manufacturers, combat engineers, the U. S. Army Engineer School (USAES), and the U. S. Army Infantry School will decide which concepts should be developed further. If the USA-CERL prototype is selected for further development, the final product will be referenced in Field Manual (FM) 5-34, *Engineer Field Data* (Headquarters, Department of the Army [HQDA], September 1976), and FM 5-103, *Survivability* (HQDA, June 1985).

2 DESIGN REQUIREMENTS

The design requirements for the OHC-IFP were developed by the U. S. Army Infantry School and outlined in TRADOC's O&O Plan. Further requirements were added as a result of joint working group meetings between BRDEC, the Infantry School, USAES, the Army Materiel Command (AMC), and USA-CERL.[1]

Size and Shape

The O&O Plan defines the standard foxhole as a hole 24 in. wide and 36 in. long. The depth varies according to the height of the soldier using it and the terrain in which it is placed. A two-man foxhole is 72 in. long and 24 in. wide. The OHC-IFP is required to fit over a one-man foxhole and to be adaptable to fit over a two-man foxhole. It has been determined that between 16 and 18 in. of headroom is required for a soldier to fire his* rifle. The overhead cover support system is therefore required to provide and maintain a minimum of 16 in. of headroom and a maximum of 18 in.

The OHC-IFP must allow soldiers to fire from under cover (i.e., they do not have to come out from under it to fire and engage an enemy). Soldiers also must be permitted a range of fire at a 45 degree angle from the front of the foxhole to provide interlocking fire (Figure 1).** A further requirement is that there be no left and right half to the OHC system.

Weight and Volume

To provide a lightweight, man-portable system, a maximum weight for the IFP-OHC is established at 10 lb. It is to be designed so that when packaged in a carrying configuration, the volume of the cover support system is compatible with the Army's "Alice" pack (backpack). Initially, it was anticipated that soldiers would carry the OHC-IFP in the two side pouches, approximately 20 by 8 by 5 in. in volume for each pouch. Later, it was decided to attach the cover supports to the outside of the pack. The volume requirement was then increased to a maximum of two packs, 20 by 16 by 5 in.

Loading Parameters

To protect soldiers from direct small arms fire and flying debris, the OHC system must withstand a static load of 24 in. wet soil (about 120 lb/cu ft) for 2 weeks. Also, the structure must not collapse when subjected to a shock wave of 15 pounds per square inch (psi) for 3 to 5 msec.

---

[1] R. A. Eubanks, *Overhead Cover for Individual Fighting Position: Feasibility Study*, Technical Report M-86/20/ADA172115 (U. S. Army Construction Engineering Research Laboratory [USA-CERL], August 1986).

*For convenience, the male pronoun is used in this report to indicate both genders.

**Figures and tables follow each chapter.

Temperature Range

The covers must be able to be stored and transported in temperatures ranging between -32 and 145°F. In addition, they must be able to be placed in soils within a temperature range of 32 to 145°F.

Reusability

The overhead covers must be resistant to fungi, water leakage, soil ingredients, and weapons chemicals. They also must withstand 6 cycles of chemical decontamination and 30 cycles of assembly and disassembly.

Cost

The manufacturing cost of each cover support system is to be $100 (1987 dollars) or less.

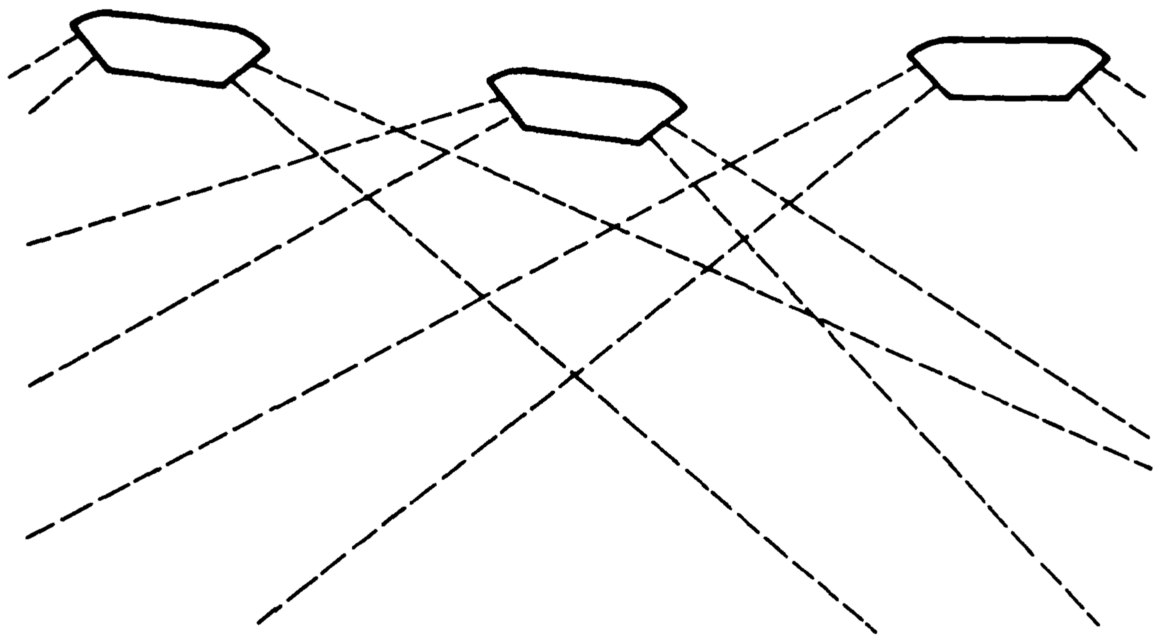


Figure 1. Interlocking fire schematic.

3 INVESTIGATION

Since the early 1980s, USA-CERL has been conducting research to evaluate OHC support systems constructed of reinforced polymeric materials. The main emphasis has been toward providing overhead cover for crew-served weapons systems. During this time, the Army identified the need for a cover to place over the two-man foxhole.

In 1981, a user group representing USAES, the U. S. Army Infantry School, the U. S. Marine Corps, and USA-CERL met to determine the shape and dimensions of the "ideal" foxhole cover. Fiberglass was chosen as the best material for the cover and a prototype was built and tested. The only disadvantage to using this OHC is that it is cumbersome and somewhat heavy to transport in the field.

The O&O Plan developed for the OHC-IFP used the fiberglass cover as a model. Except for the weight and volume restrictions in the plan, this fiberglass cover is the most desirable design. For this reason, USA-CERL designed its OHC-IFP (Figure 2) to conform as closely as possible with the fiberglass cover support developed previously. (Appendix A contains a parts list and production drawings for the USA-CERL design as completed; the figures are referenced in this chapter for readers wishing to see design details.)

Design Considerations

The cost, weight, and chemical resistance restrictions were the major factors guiding the design considerations. A feasibility study was conducted[2] to determine if a structure could be built at the low weight requirement and still support a soil load to provide overhead protection. The study concluded that the best configuration would be a fabric-covered tubular frame. Materials were then evaluated for potential use in constructing a frame (Figure 3) shaped similar to the fiberglass foxhole cover support.

In order to use fiberglass for the tubular framework, a special extruding process or mold would be required. For a limited number of prototypes--at least in initial testing--this requirement would be very expensive. Because of the limited funding ($24,000) and relatively short time available (1 year) to develop and produce the system, coupled with the fact that fewer than 100 prototypes would be made, this material option was determined to be unfeasible.

Aluminum was investigated as an alternative material that does not require special processing for shaping. Grade 6061-T6 was selected because it is strong, lightweight, easily field-weldable in case of damage, and relatively corrosion-resistant in chemical environments. To minimize weight and packaging volume and maximize stiffness of the frame members, a 1-in.-diameter aluminum tube with 0.049-in. wall thickness was selected for the main structural members of the frame.

Tubing

One prototype design that was built and tested under a 24-in. soil load had a frame made of 0.75-in.-diameter aluminum tubing with 0.065-in.-thick walls (dimensions

[2] R. A. Eubanks.

between those discussed in the earlier feasibility study).[3] Special connectors were designed, machined, and welded onto the ends of the tubes. During the load testing, several of the tubes developed cracks at the weld line. USA-CERL decided to try eliminating all welded connections on the structure because the stress experienced by the frame was at the point of stress failure for the welded aluminum.

To add stiffness to the structural members, enable a telescope-style connection on the arch rib sections to eliminate the need for welding, and reduce the weight of the frame, a 1-in.-diameter tubing with 0.049-in.-thick walls was chosen for the arch connectors and upper arch sections whereas a 0.875-in.-diameter, 0.049-in.-thick tube was chosen for the lower arch sections.

Connections

Connectors on the original overhead cover were machined to within 0.005 in. of the outside diameter of the tubing. This close tolerance kept the frame from flexing and made it very difficult to assemble and disassemble. To alleviate these problems, make the frame conform better to possible unevenness of the ground, reduce the machining costs, and add some flexibility to the shelter during shock waves from explosions, a commercially available connector was selected that has a larger gap between the tubing walls and the connector.

Connectors for the frame backbone are fastened to the aluminum tubing by set screws (Figure 4; see also Figures A5 and A6 in Appendix A). The straight and curved backbone sections are fastened to the connectors using nylon take-down button assemblies (Figure A7, Appendix A) that allow for easy assembly and disassembly.

The lower arch sections fit inside the upper section. A 0.25-in.-diameter spring pin (Figure 5) is set in each lower arch leg section to limit the seating and keep the leg from twisting under loading. These pins seat in the grooves on the end of the upper arch section (see Figures A5 and A6 in Appendix A). A 47-in.-long elastic shock cord ties together the entire arch to reduce the number of loose parts, speed assembly, and keep the assembled arch section together and the arch baseplates from coming off (Figure 6).

OHC-IFP Tube Baseplates

A design feature that must be taken into account is the need for some method of spreading the load on the overhead cover support into the ground. Due to the mechanics of some soils, they will not support much load, so that a way to distribute that load is needed. A bearing plate was designed for each leg of the overhead cover to spread the load of the support system and soil cover to minimize sinking.

The tube baseplates into which the end of the arch tubes fit (Figure 7) are made of 3-in.-wide by 0.0625-in.-thick glass-reinforced plastic (Scotchply* Crossply 7) with a 0.25-in.-thick linen-reinforced phenolic seat (Garolite LE). Figures A8 and A9 in Appendix A show details. Those tubes that do not have a baseplate have a shock-cord stop made of 0.5-in. Garolite LE tubing (Figure A10, Appendix A). A 0.25-in.-diameter hole is in the center of the baseplate seat to allow the elastic shock cord to pass through. This

[3] R. A. Eubanks.

*Registered Trademark of 3M, St. Paul, MN.

shock cord is secured by tying a knot in the end, thus preventing it from slipping out of the baseplates or cord retainer.

Fabric Cover

Initial loading tests were conducted using a standard Army poncho as the fabric cover. Nylon fastening straps were sewn to the ponchos and the head hole was sewn shut. The poncho has a high degree of stretch when subjected to loads, so that additional nylon straps were required to keep the fabric sag from filling the space under the frame.

To minimize stretching of the fabric used for the final prototype, a material with a polyester base was chosen. Because of its easy availability and, further, to provide chemical inertness, fungal resistance, and a moisture barrier at a minimum of weight and cost, an 8-oz/sq yd polyvinyl chloride (PVC) laminated fabric was selected. Table 1 lists physical properties of the cover fabric.

Assuming that a soil with a density of 120 lb/cu ft is placed on the OHC-IFP to a depth of 24 in., the total load on the cover support system is 6480 lb. This configuration loads the structure to 1.67 psi with a maximum fabric force of 30 lb/in. for the worst case. The tear and tensile strengths of this fabric far exceed the extreme loadings it may experience.

The fabric cover was designed so that the OHC-IFP would have no left or right half. To meet this criterion, the fabric had to be designed with two sections (for details, see Figures A11 through A14 in Appendix A). The design also provides for several overhead covers to be fastened together, making a continuous fabric cover (Figure 8).

Hook-and-loop fasteners were selected to fasten the fabric sections to each other and to the aluminum frame. This type of fastener is less expensive than strap-and-buckle fasteners and provides a more continuous seal.

Packaging

USA-CERL packaged its system based on the original volume dimensions that had been specified (see Chapter 2, **Weight and Volume**). Fabric pouches were made from 4-oz nylon fabric for carrying the OHC-IFP. Each pouch is 5 in. wide, 8 in. long, and 20 in. deep with a 0.25-in. cord drawstring to close the top (Figure A15 in Appendix A). These two pouches are attached to the Alice pack (Figure 9) using 0.75-in. nylon strap and the drawstrings. The weight of the OHC-IFP when packaged in the pouches is 8.8 lb. For shipping the cover supports, a complete OHC-IFP is placed in a cardboard box 21 in. long, 10 in. wide, and 10.25 in. deep.

Cost

The combined material and manufacturing cost for 65 prototypes was $170.24 for each overhead cover support system. (Appendix A lists individual system components.) This cost does not include labor for packaging and final part assembly. For mass production of the OHC-IFP, this cost would be greatly reduced and the final product should cost less than $100 each.

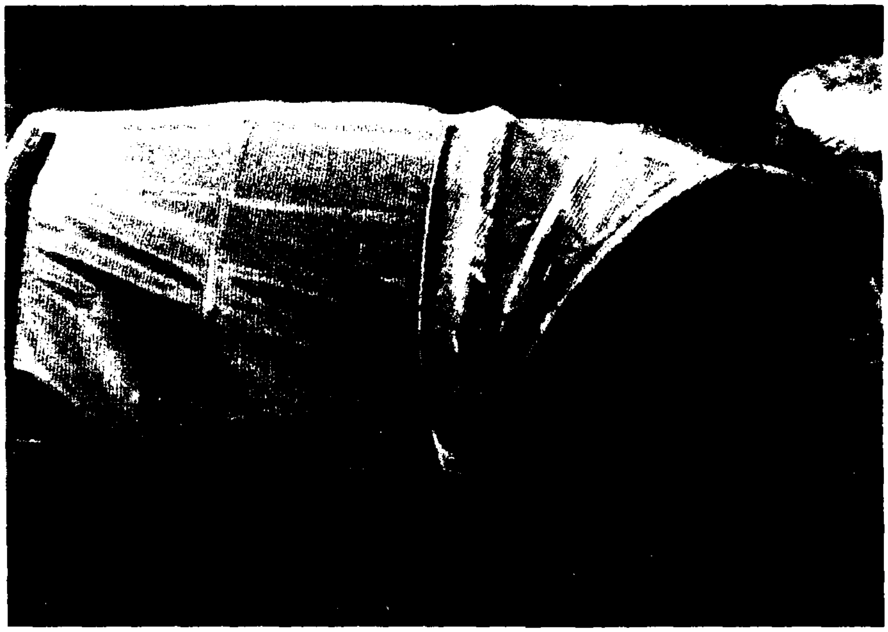


Figure 2. OHC-IFP.

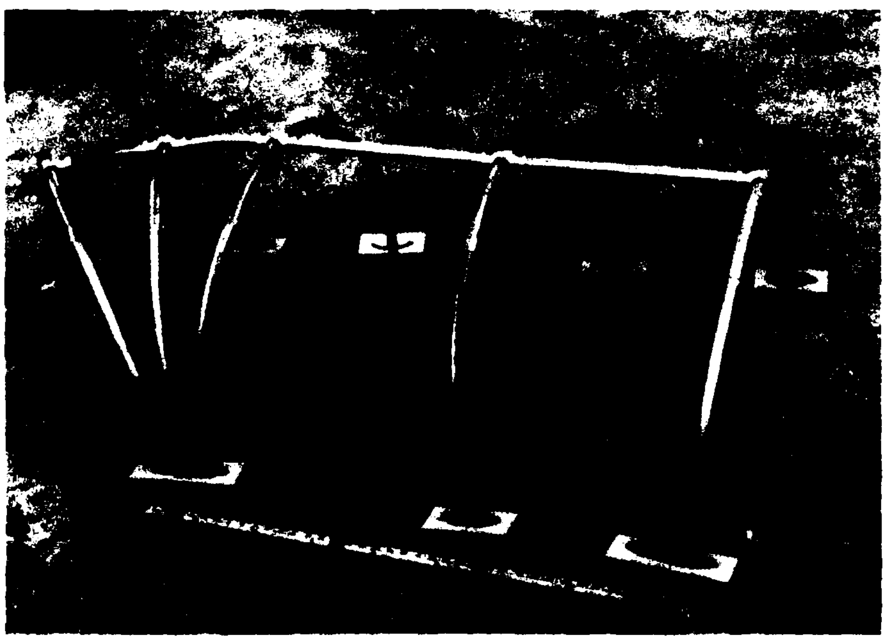


Figure 3. OHC-IFP frame.

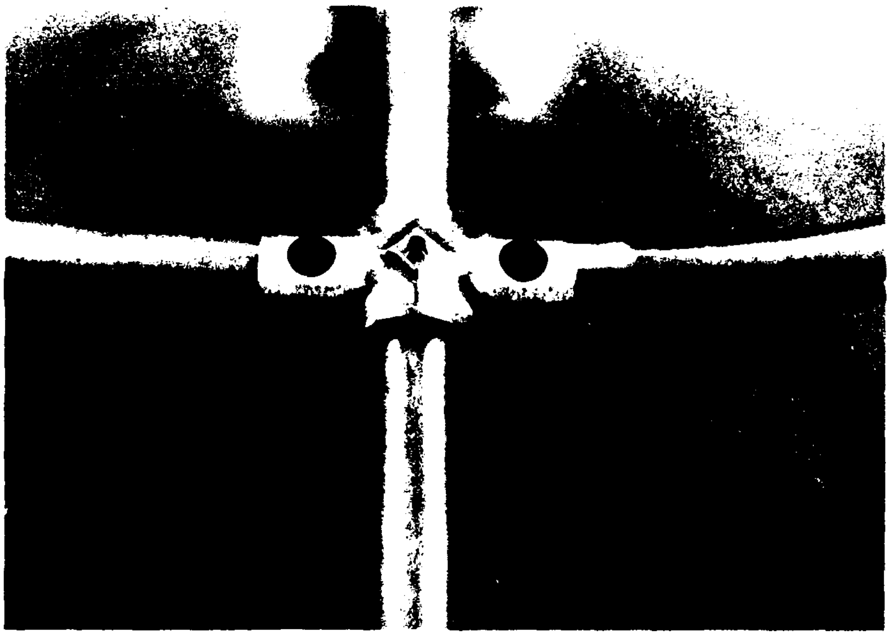


Figure 4. Tube connectors.

Figure 5. Lower arch section and spring pin.

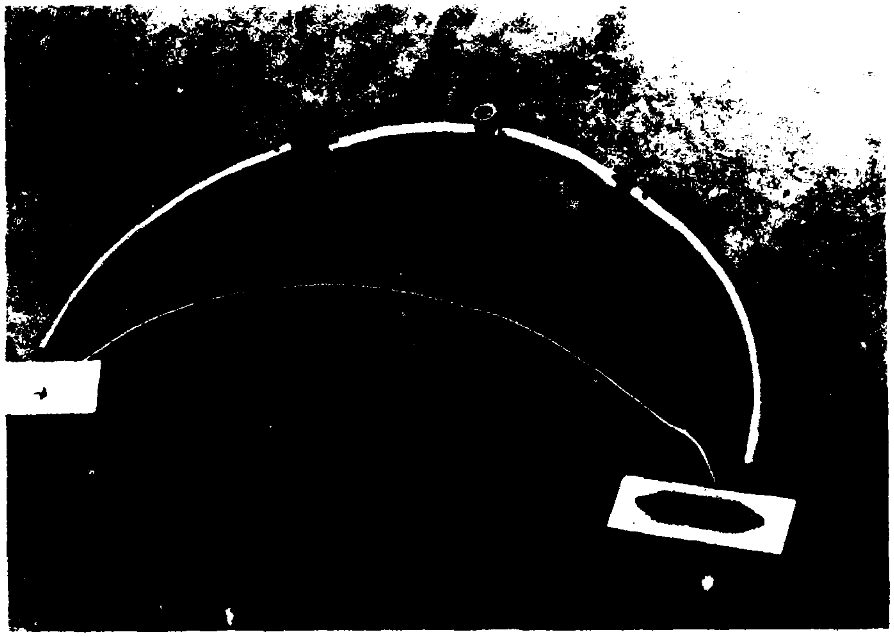


Figure 6. Elastic shock cord.

Figure 7. Triple-tube baseplate.

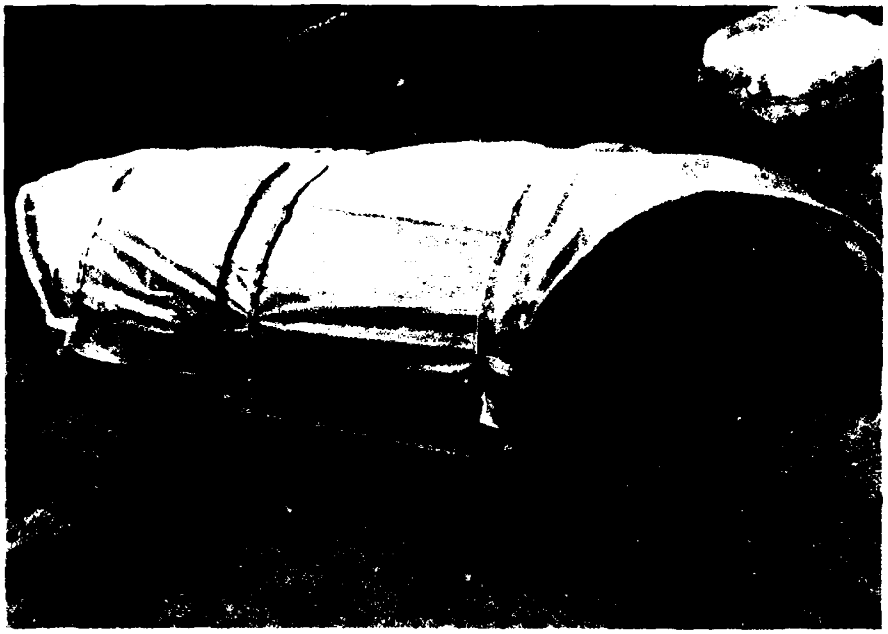


Figure 8. Two attached OHC-IFPs.

Figure 9. OHC-IFP attached to "Alice" pack.

Table 1

Physical Properties of OHC-IFP Cover Fabric*

Type of fabric	Clear PVC laminate
Yarn type	Polyester
Yarn weave construction, W x F**	8 x 4
Weight, oz/yd	8 - 9
Tear strength, W x F, lb	60 x 50
Tensile strength, W x F, lb/in.	170 x 100
Flame rating by ASTM E-162, sec.	25

*The manufacturer is West Point Pepperell. The weave number for the fabric is 613-08.
**Weave (W) by fill (F).

4 TESTING AND ANALYSIS

The USA-CERL prototype OHC-IFP system was subjected to in-house tests to analyze material and structural properties. It was then tested in the field by an independent customer test agency to determine performance characteristics.

In-House Tests

USA-CERL first analyzed the materials at the recommended service temperatures. Only materials believed able to withstand temperatures between -32 and 145°F were used in the design. As Table 2 shows, actual service temperatures[4] for these materials exceed the maximum requirements; in addition, all materials are serviceable at the -32°F minimum.

Next, a structural analysis was performed on the frame assuming that (1) the base of the frame was fixed and (2) the base was allowed to spread out 1 in. during loading. (If the cover is loaded properly, this amount of spreading will never occur. Appendix B describes the assembly and loading procedures.) Appendix C contains the mathematical results for the structural framework analysis. For both instances (1 and 2), the calculated stress in the structure remained less than the maximum allowable stresses.

A prototype was constructed and tested for 15 days with a load of 24 in. of sandy clay (Figure 10). This soil cover was placed on the overhead cover support and kept saturated by watering it daily (except on rainy days). On the third day, 6 in. of soil was added to compensate for settling. The soil was wetted for 6 days during the test by showers and thunderstorms. A dial gauge (Figure 11) was placed under the center arch in the straight section and the overhead movement was recorded at different intervals over the 15 days. Table 3 and Figure 12 show the overhead deflections observed during this test period. When the structure was removed, it was noted that the baseplate had sunk into the ground somewhat and this condition may have caused much of the observed deflection.

To eliminate the effect of sinking, the test was repeated indoors on a concrete floor using 36 in. of slightly damp sand as the cover. The sand load weighed 32.5 percent more than the 24 in. of saturated clay (Table 4), making the second test a worst-case situation. The test lasted 30 days. During this time, there was no measurable deflection of the cover support frame, indicating that the previously observed deflection results were indeed due to sinking.

Another in-house test was conducted to determine the fabric cover's resistance to DS-2, the agent used for chemical decontamination by the Army. PVC can react with some of the components of DS-2, but the resistance to six washings with this chemical was not known. The normal decontamination procedure used by troops in the field is to either spray DS-2 on a contaminated surface or dip the part in a tub of DS-2, allow it to stand for approximately 15 min, and then wash off the residue with hot soapy water.[5]

---

[4] *Thermoplastics and Thermosets, Desk-Top Data Bank*, 8th Ed. (D.A.T.A. Inc., San Diego, CA).

[5] Field Manual (FM) 3-5, *NBC Decontamination* (Headquarters, Department of the Army, June 1985).

A solution was prepared using the chemicals and percentages comprising DS-2: 0.015 oz sodium hydroxide, 0.2 oz ethylene glycol monoethyl ether, and 0.51 oz diethylenetriamine. The sodium hydroxide would not dissolve in a straight mixture of these chemicals, so the solution was reformulated by first dissolving the sodium hydroxide in 0.015 oz hot water and then adding the other chemicals.

Fabric samples were cut 4 in. long and 1 in. wide. Samples to be tested were thoroughly wetted with solution by submergence; then they were removed and allowed to lay on a piece of tissue paper for a minimum of 30 min. After this time, they were washed in hot soapy water, followed by three rinses of hot water. Four samples were not treated, while four other samples were treated using one wash cycle, another four using two cycles, and so on to six cycles for the final four samples. There was some discoloration of the fabric when exposed to the DS-2 solution (Figure 13). The more the exposure, the greater the discoloration. This change is an indication that DS-2 reacts with the PVC. This test was also used on all other parts of the OHC-IFP. There was no discoloration or visible material degradation in any other component.

Tensile strength of the samples was tested using a United TM-1-10 test machine. Table 5 describes the tensile test results and Figure 14 is a graph of the average strengths related to the number of wash cycles. These results show an overall strength reduction of 13.2 percent. Therefore, it was concluded that the DS-2 solution reacts with the fabric material, but it does not affect the fabric strength enough over six cycles to preclude using this material for the overhead covers. The polyester base that gives the fabric its strength is not affected by six washings with DS-2. However, the DS-2 weakens the PVC matrix and makes fiber pull out much easier.

Since a customer test was planned to evaluate the OHC-IFP's usability and reusability, no in-house tests were conducted to determine the number of times the structure could be assembled/disassembled.

Field Test

A customer test was conducted by ADEA and the results are summarized in Appendix D. These tests revealed some major problems with the O&O Plan on which the design was based. In particular, the foxhole size needed to be redefined and the maximum height of the OHC needed to be much lower to be acceptable. (Those tested presented too high a profile and were too easily detectable on the ground.) These findings resulted in a decision by the U. S. Army Infantry School to rewrite the O&O Plan for the OHC and begin designing overhead cover support systems to meet the new requirements.

The main problem observed with USA-CERL's OHC-IFP was that several of the spring pins in the frame legs came out and were easily lost during the test, making the cover support system unusable. Other conditions that made the cover support more difficult to assemble were (1) the elastic shock cord was sometimes cut by sharp edges on the aluminum tubing, (2) the hook-and-latch fastening material on the fabric covers would not work well after becoming coated with mud, (3) the take-down button assemblies would become contaminated with sand and fail to work, and (4) two covers failed due to improper loading procedure; the tubes twisted in the aluminum crosses and the covers fell sideways to the ground.

Loss of the spring pins can be corrected successfully by placing a short length of surgical elastic tubing on the pins inside the tubes. To prevent shock cords from being cut, a plastic tube insert can be used to keep the cord away from the aluminum edges; or, the edges can be chambered. A rubber cover for the take-down button assemblies will keep the sand out, and the fabric can be fastened to the frame using buckles or snaps rather than the hook-and-latch fabric fasteners. Finally, to reduce the tendency of the framework to twist during loading, long set screws can be inserted through the top of the arch tube to pin the bottom of the tube to the cross-tube connector.

Only the recommended corrective measure for the pin loss was evaluated. By using a tube with an inside diameter slightly smaller than the pin diameter, removal and loss of the pins was very difficult and it is highly unlikely that this problem would recur.

Table 2

Service Temperatures of Plastics Used in the OHC-IFP*

Plastic Material	Maximum Service Temperature (°F)
Polyvinyl chloride	150 - 220
Reinforced epoxy	350 - 450
Reinforced phenolic	300 - 350
Polyester	200 - 250
Reinforced nylon	175 - 300
Aluminum**	400

*Source: *Thermoplastics and Thermosets, Desk-top Data Bank*, 8th Ed. (D.A.T.A. Inc., San Diego, CA), pp A-18 - A-28. Used with permission.
**Source: *Specifications for Aluminum Structures*, 4th Ed., Construction Manual Series, Section 1 (The Aluminum Association, Inc., Washington, D.C., April 1982), p 55.

Figure 10. OHC-IFP being load-tested.

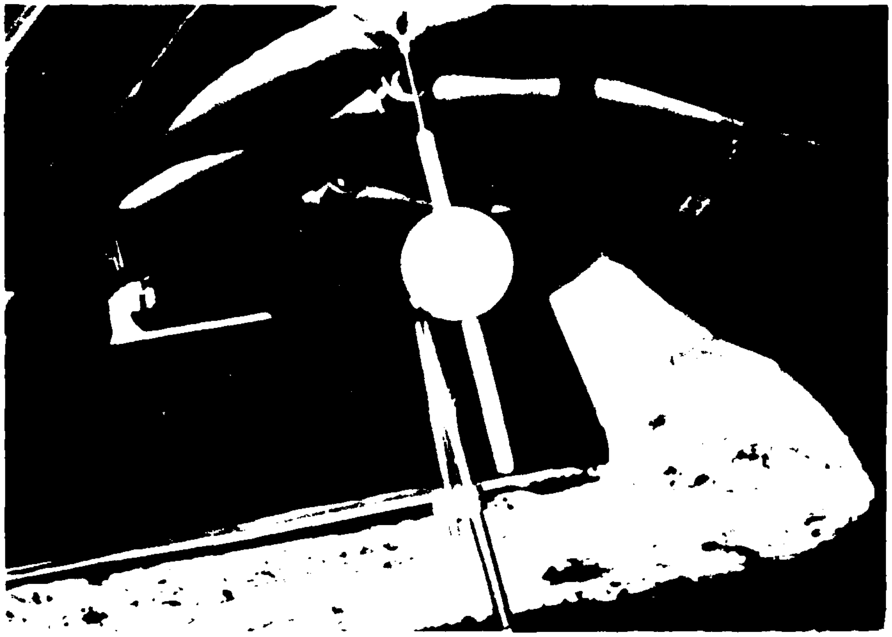


Figure 11. Load test dial gauge.

Table 3

Load Test Deflections

Lapse Time (hr)	Total Deflection (in.)	Change (in.)	Change per Hour (in.)
0	0.38	-	0
66.5	0.435	0.055	0.000827
90.5	0.4495	0.0145	0.000604
115.5	0.4522	0.0027	0.000108
234.5	0.4958	0.436	0.000366
259.5	0.499	0.0032	0.000128
283.2	0.502	0.003	0.000126
306.5	0.4991	-0.0029	-0.00012
330.5	0.5	0.009	0.000037
336.0	0.5011	0.0011	0.0002

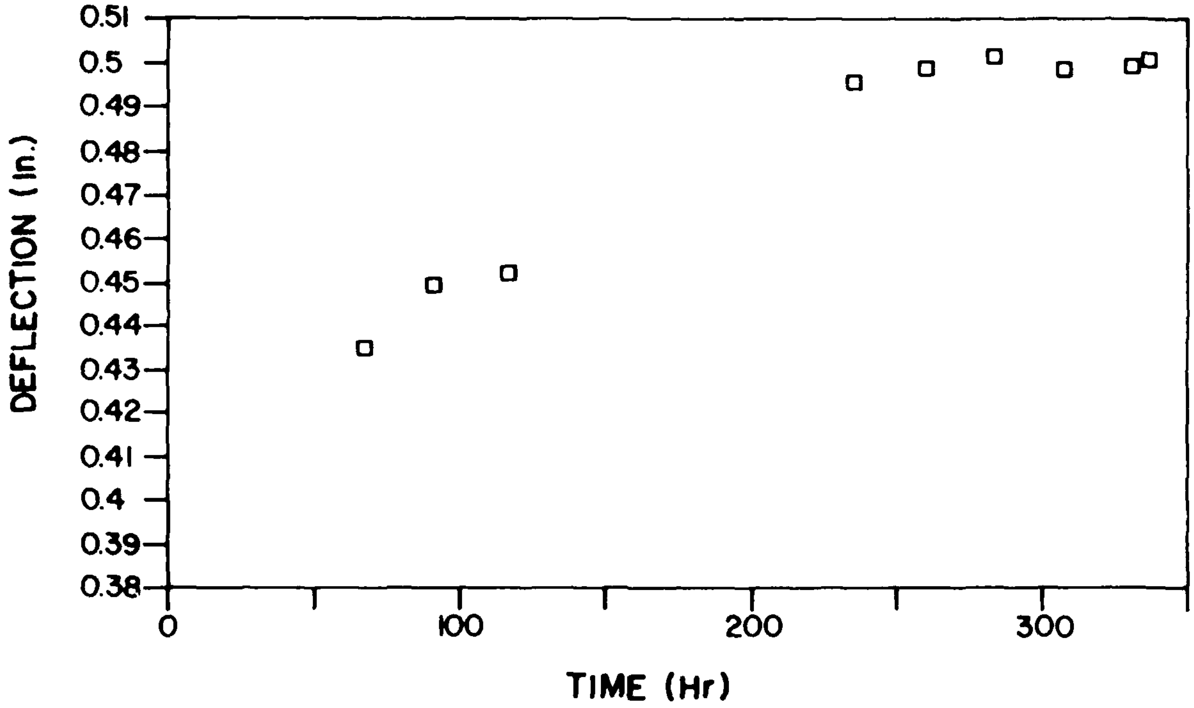


Figure 12. Load test deflections.

Table 4

Unit Weights of Typical Soils

Soil Type	Loose Weight (lb/cu yd)	Loose Weight (lb/cu ft)	Compacted Weight (lb/cu yd)	Compacted Weight (lb/cu ft)
Dry excavated clay	1840	68	2560	95
Wet excavated clay	3080	114	4280	159
Natural bed clay	2130	79	2960	110
Dry excavated loam	2100	78	2620	97
Moist excavated loam	2430	90	3040	113
Wet excavated loam	2700	100	3380	125
Packed, dense loam	3100	115	3880	144
Packed, dry loam	2560	95	3200	119
Loose sand and clay	2700	100	3380	125
Compacted sand and clay	4050	150	-	-
Dry, loose sand	2400	89	2690	100
Slightly damp sand	2850	106	2690	118
Wet sand	3120	116	3490	129
Packed, wet sand	3120	116	3490	129
Topsoil	1620	60	2320	86

*Source: John Havers and Frank Stubbs, *Handbook of Heavy Construction*, 2nd Ed. (McGraw-Hill, 1971), pp 6-10, 6-11. Used with permission.

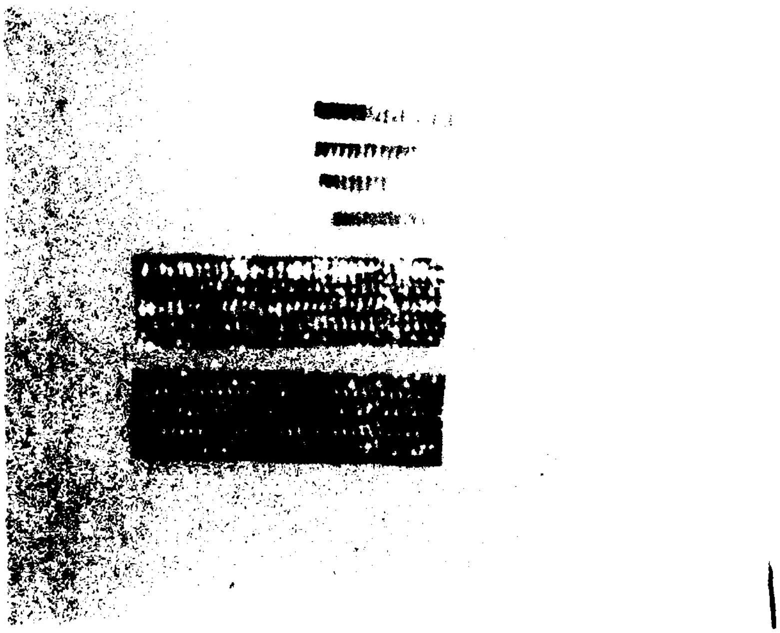


Figure 13. Fabric discoloration after DS-2 treatments.

Table 5

Fabric Tensile Strength Test Results

Test Number	Number DS-2 Washes	Fabric Orientation*	Tensile Strength (lb/in)	DS-2 Wash Duration (min)
1	0	F	34.9	0
2	0	F	43.4	0
3	0	F	72.0	0
4	0	F	66.6	0
5	0	F	49.1	0
6	0	F	67.6	0
7	0	F	59.7	0
8	0	W	200.5	0
9	0	W	231.6	0
10	0	W	218.7	0
11	0	W	220.2	0
12	0	W	205.9	9
13	0	W	229.7	0
14	0	W	191.3	0
15	1	W	207.0	47
16	1	W	185.1	47
17	2	W	181.7	41
18	2	W	199.2	41
19	3	W	162.2	70
20	3	W	173.2	70
21	4	W	194.5	70
22	4	W	157.7	33
23	5	W	194.8	33
24	5	W	184.6	37
25	6	W	193.5	42
26	6	W	175.7	42
27	6	W	196.6	42
28	6	W	162.5	42
29	6	W	177.6	42

*F = fill; W = weave.

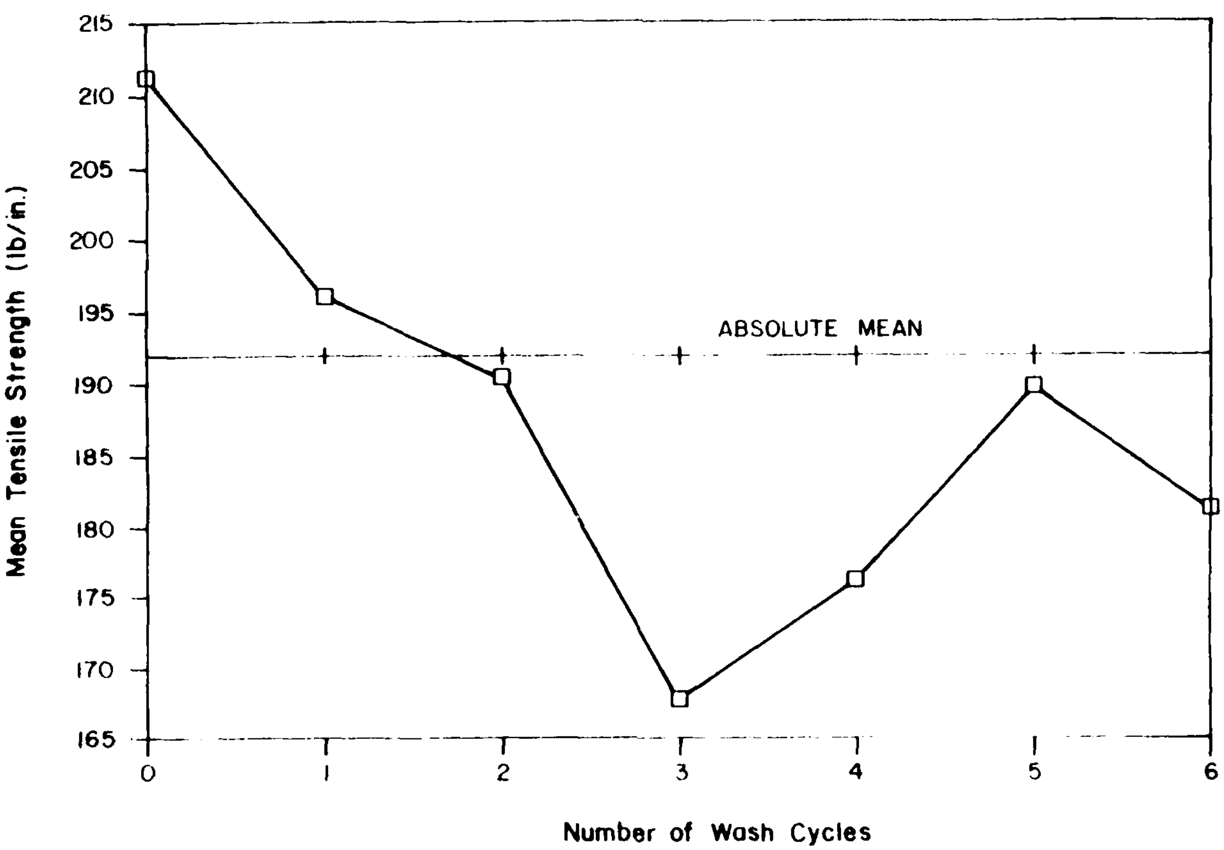


Figure 14. Fabric tensile test results.

5 CONCLUSIONS AND RECOMMENDATIONS

The OHC-IFP developed by USA-CERL meets the requirements for overhead cover support for individual fighting positions originally established by the U. S. Army Infantry School, the USAES, and BRDEC in the O&O Plan which TRADOC approved in December 1984.

The weight requirement for the OHC support system is 10 lb or less; USA-CERL's OHC-IFP weighs 8.8 lb. In terms of packaging requirements, the OHC-IFP must fit on the Army's Alice pack and be contained in no more than two packs, each 20 by 16 by 5 in.; the system developed by USA-CERL fits on the Alice pack using nylon straps and consists of two packs which are 20 by 8 by 5 in. The OHC-IFP is to provide between 16 and 18 in. of headroom above ground level and allow a soldier to fire outward at a 45 degree angle from the front while under cover. The OHC-IFP developed by USA-CERL was the only one among several prototypes in the customer test that allowed firing from under cover and one of two designs tested that met the height requirement.

None of the materials used in this OHC-IFP will be affected by anticipated temperature and chemical environments (-32 to 145°F and 6 cycles of chemical decontamination) and, with minor modifications, will withstand up to 30 cycles of assembly, loading, unloading, and disassembly. The USA-CERL OHC-IFP will support the required 24 in. of wet soil for 2 weeks and, when mass produced, is projected to cost $100 (1987 dollars) or less. The requirement for withstanding an explosive shock wave of 15 psi for 3 to 5 msec was not tested because of limited funding and a decision by the material developer and user to change the requirements for an overhead cover system. The explosive shock wave, however, was a design consideration in choosing materials and fittings.

It is recommended that the material developers and combat engineers continue testing this OHC support system for application over foxholes and as a cover for entryways to underground bunkers and command and control centers. It is further recommended that it be tested as a cover for individual soldiers fighting in rocky terrain where it is impossible to dig foxholes; for this application, the soldier would lie prone under the OHC-IFP to receive protection provided by sandbags while fighting.

METRIC CONVERSIONS

1 in. = 25.4 mm
1 lb = 0.453 kg
1 oz = 28.3495 g
1 lb/in. = 17.8580 kg/m
1 psi = 6.89 kPa
(°F-32) x 0.55 = °C

APPENDIX A:

OHC-IFP PARTS LIST AND PRODUCTION DRAWINGS

Table A1 lists the materials, parts, vendors, and contractors used in producing the OHC-IFP developed by USA-CERL. Figures A1 through A15 are the production drawings.

Table A1

OHC-IFP Parts List

Part Name	Drawing Number	Material	Vendor or Supplying Contractor Name, Address, and Phone Number
Upper Arch Section	A1	Aluminum (6061-T6)	Material Source: Central Steel & Wire Co. 3000 W. 51st St. Chicago, IL 60680 (312) 471-3800 Fabricating Contractor: Silver Machine & Welding Shop 712 N. Champaign Champaign, IL 61820 (217) 359-5717
Lower Arch Section	A2	Aluminum (6061-T6)	Material Source: Central Steel & Wire Co. Fabricating Contractor: Silver Machine & Welding Shop
Main Arch Connector	A3	Aluminum (6061-T6)	Material Source: Central Steel & Wire Co. Fabricating Contractor: Silver Machine & Welding Shop
Firing Port Arch Connector	A4	Aluminum (6061-T6)	Material Source: Central Steel & Wire Co. Fabricating Contractor: Silver Machine & Welding Shop
Cross-Tube Connector	A5	Aluminum (6063-T6)	Material Source: McMaster-Carr Supply Co. P.O. Box 4355 Chicago, IL 60680 (312) 833-0300 Fabricating Contractor: Silver Machine & Welding Shop

Table A1 (Cont'd)

Part Name	Drawing Number	Material	Vendor or Supplying Contractor Name, Address, and Phone Number
End-Tube Connector	A6	Aluminum (6063-T6)	Material Source: McMaster-Carr Supply Co. Fabricating Contractor: Silver Machine & Welding Shop
Spring Pin		Steel	Material Source: Silver Machine & Welding Shop
Take-Down Button Assembly	A7	Nylon	Material Source: Carlisle Paddles P.O. Box 488 4562 N. Downriver Road Grayling, MI 49738 (517) 348-9886
Triple-Tube Baseplate	A8	Garolite LE	Material Source: McMaster-Carr Supply Co. Fabricating Source: Silver Machine & Welding Shop
		Scotchply	Material Source: Structural Product Dept. /3M 2207 E. 3M Center St. Paul, MN 55144
Single-Tube Baseplate	A9	Garolite LE	Material Source: McMaster-Carr Supply Co. Fabricating Source: Silver Machine & Welding Shop
		Scotchply	Material Source: Structural Product Dept. /3M
Pop Rivets		Aluminum	Material Source: Black & Company Hardware 112 W. Green Champaign, IL 61820 (217) 352-5167
Elastic Shock Cord			Material Source: McMaster-Carr Supply Co.
Elastic Shock Cord Stop	A10	Garolite LE	Material Source: McMaster-Carr Supply Co.

Table A1 (Cont'd)

Part Name	Drawing Number	Material	Vendor or Supplying Contractor Name, Address, and Phone Number
Main Fabric Cover	A11, A12	PVC Lam.	Material Source: West Point Pepperell Virginia Bond Cote P.O. Box 729 Pulaski, VA 24301 (703) 674-0674 Fabricating Contractor: George Strode Awnings 309 S. Neil Champaign, IL 61820 (217) 352-5451
Firing Port Fabric Cover	A13, A14	PVC Lam.	Material Source: West Point Pepperell Fabricating Contractor: George Strode Awnings
OHC-IFP Carrying Pouch	A15	Nylon	Material Source: George B. Carpenter Co. 401 N. Ogden Ave. Chicago, IL 60622 (312) 666-8700 Fabricating Contractor: George Strode Awnings
#3-1/4 Size Cord		Cotton	Material Source: George Strode Awnings

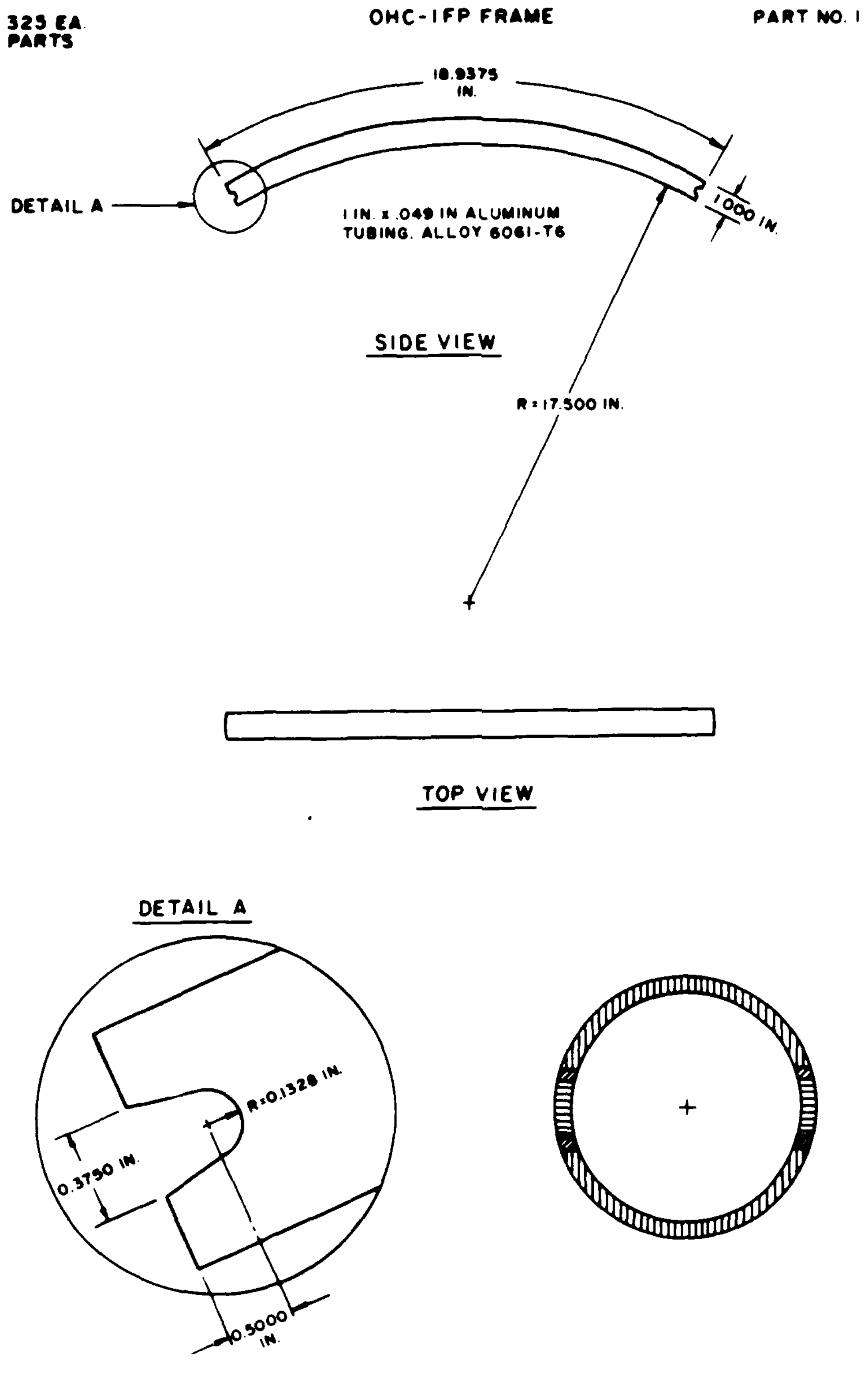


Figure A1. Upper arch section.

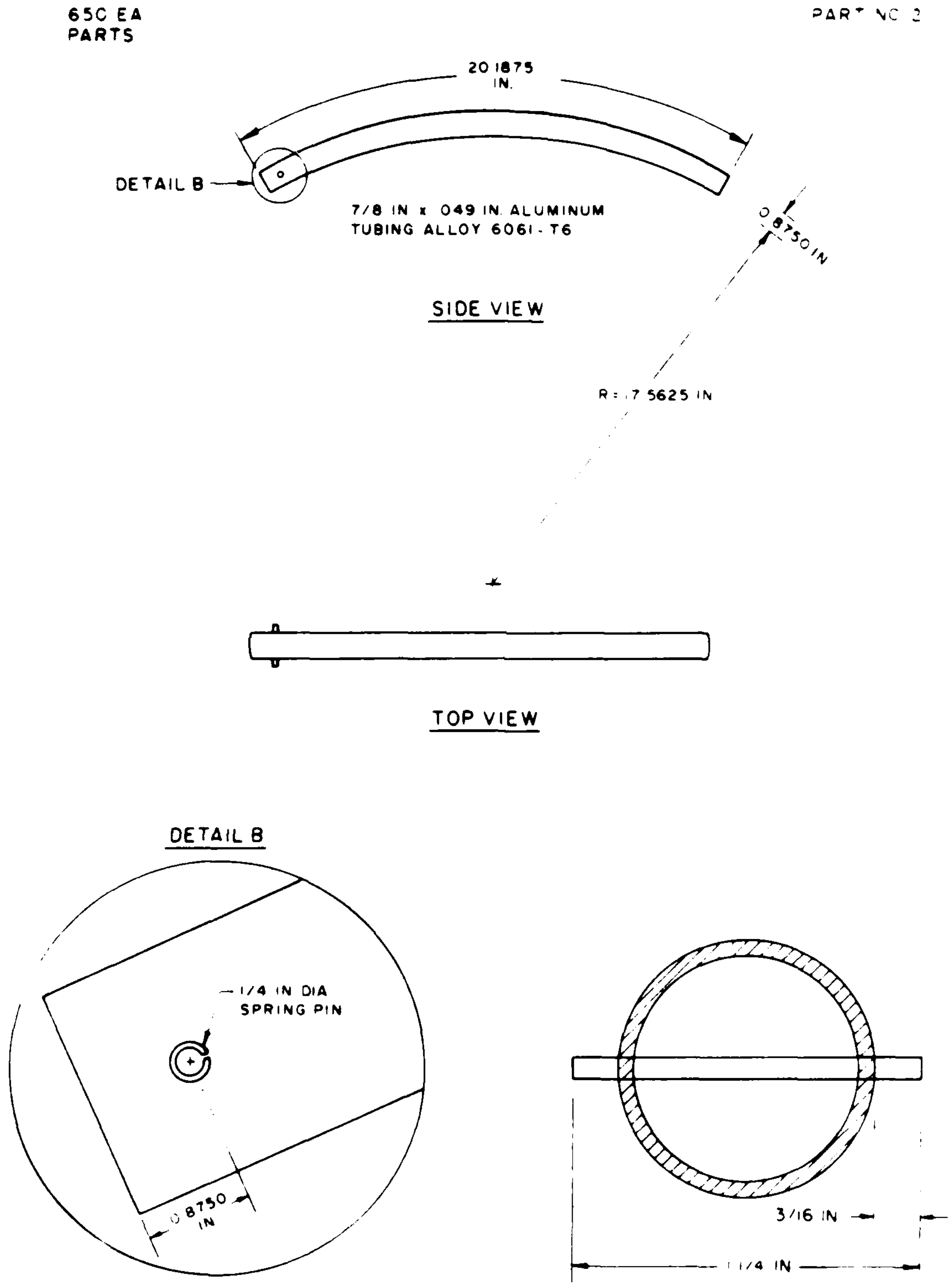
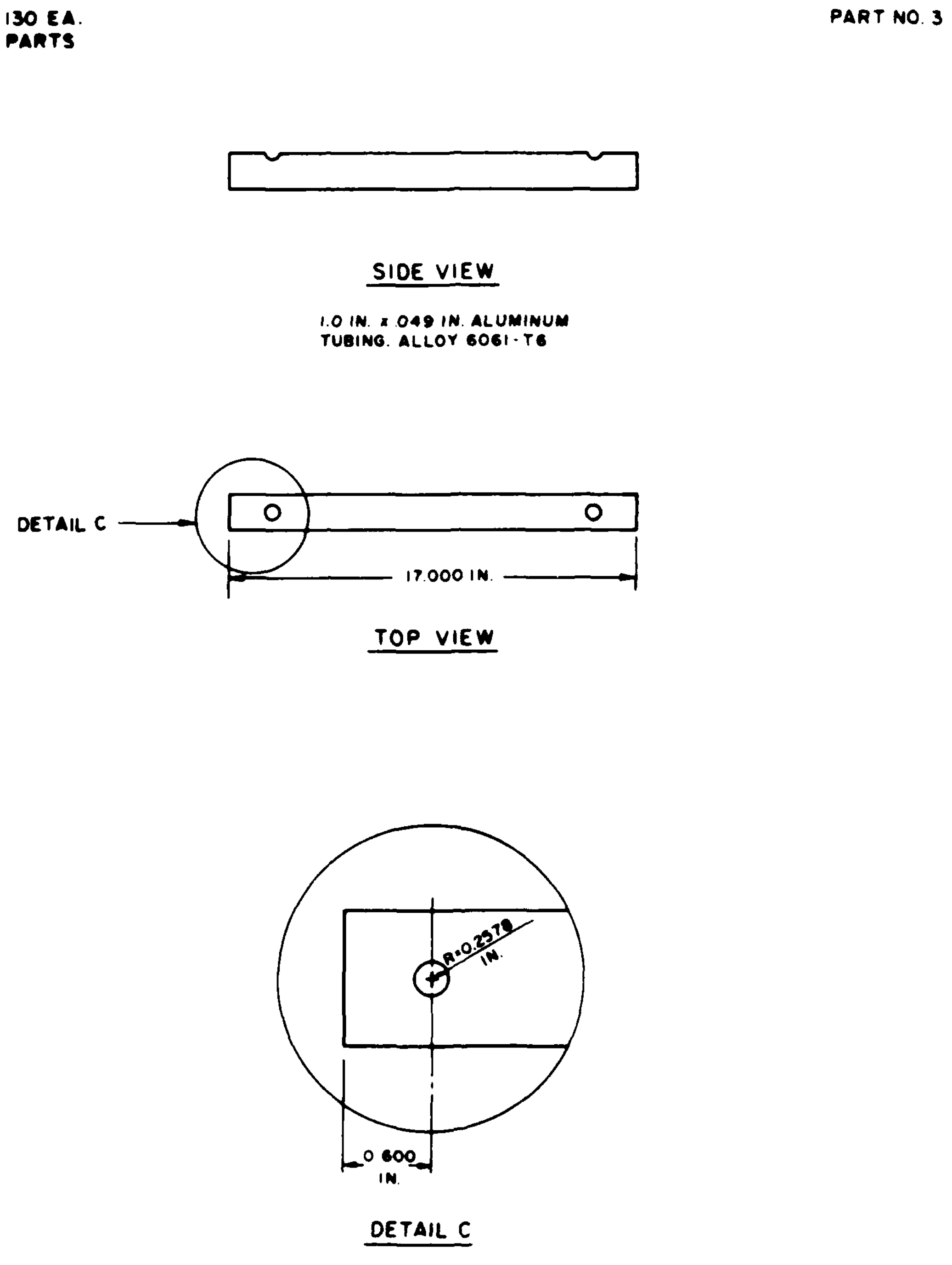


Figure A2. Lower arch section.



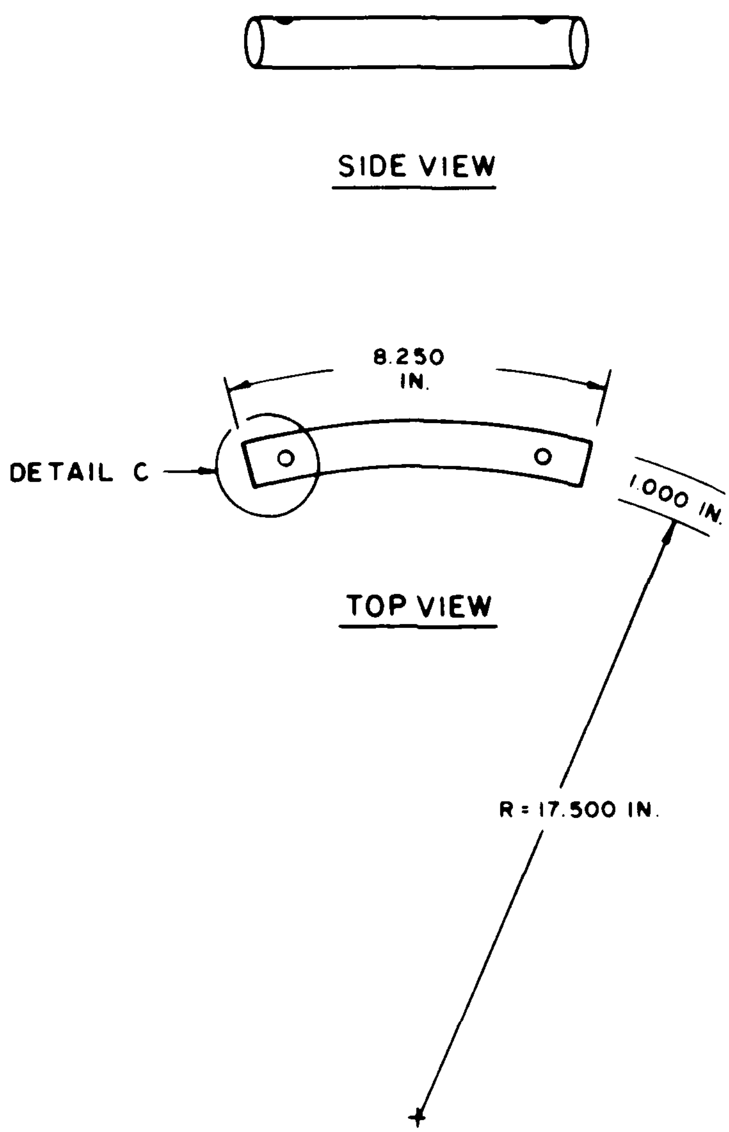
NOTE HOLES AT EACH END ARE IDENTICAL AND SHALL BE IN THE SAME PLANE.

Figure A3. Main arch connector.

130 EA.
PARTS

PART NO. 4

1.0 IN. x .049 IN
ALUMINUM TUBING
ALLOY 6061-T6



NOTE: HOLES AT EACH END ARE IDENTICAL AND
SHALL BE IN THE SAME PLANE.

Figure A4. Firing port arch connector.

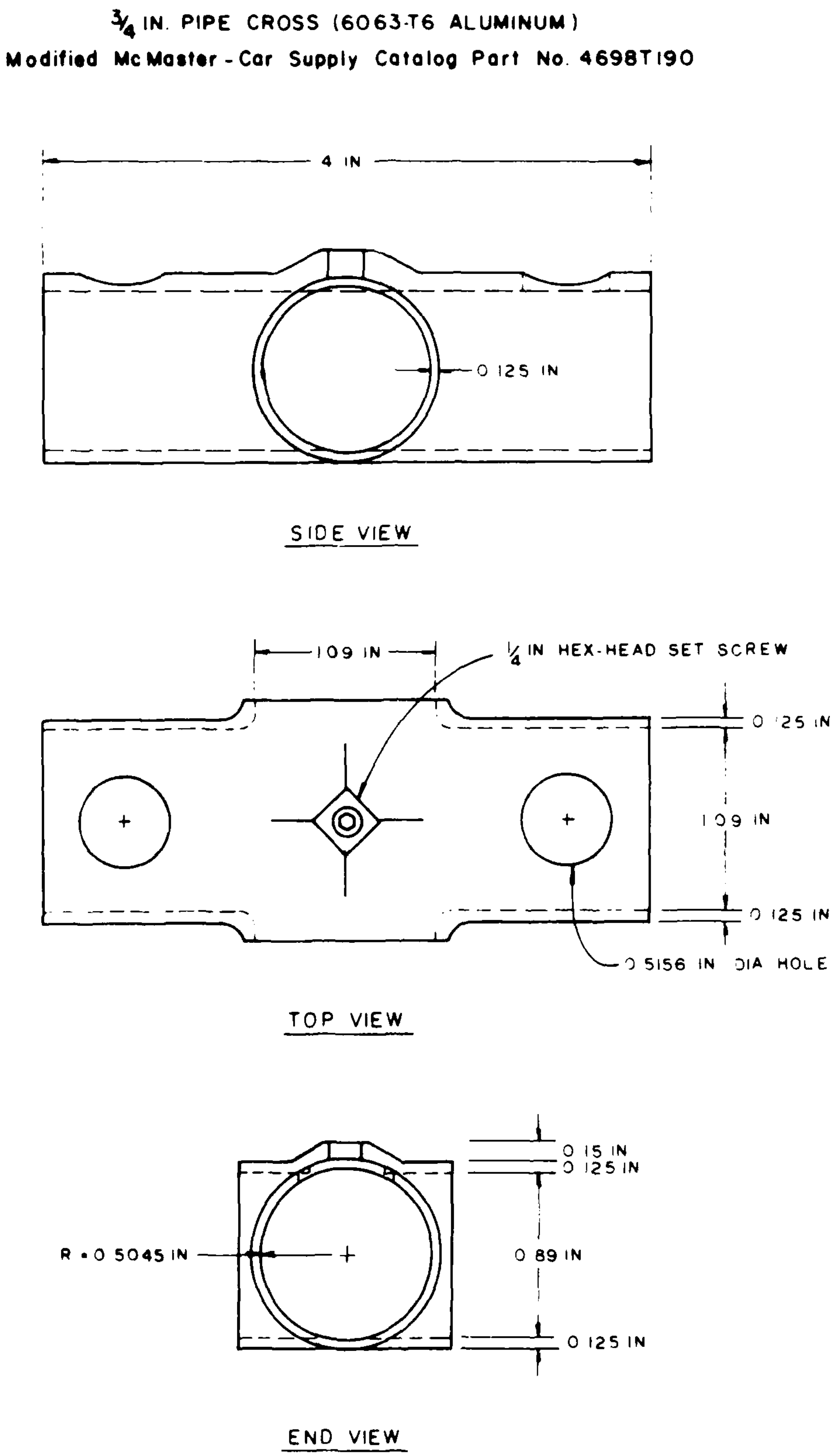


Figure A5. Cross-tube connector.

$^3/_4$ IN. PIPE TEE (6063-T6 ALUMINUM)

Modified McMaster-Car Supply Catalog Part No. 4698T140

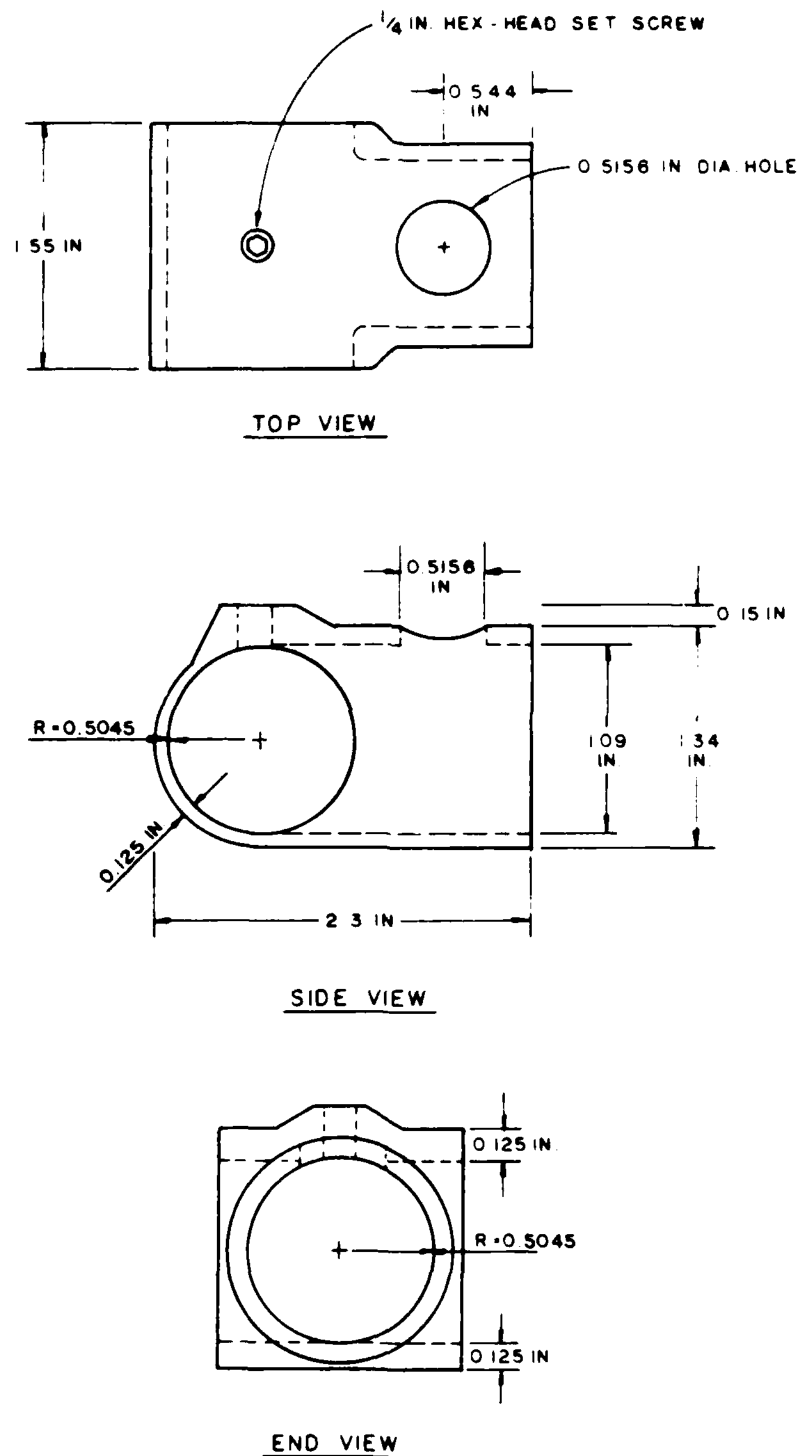


Figure A6. End-tube connector.

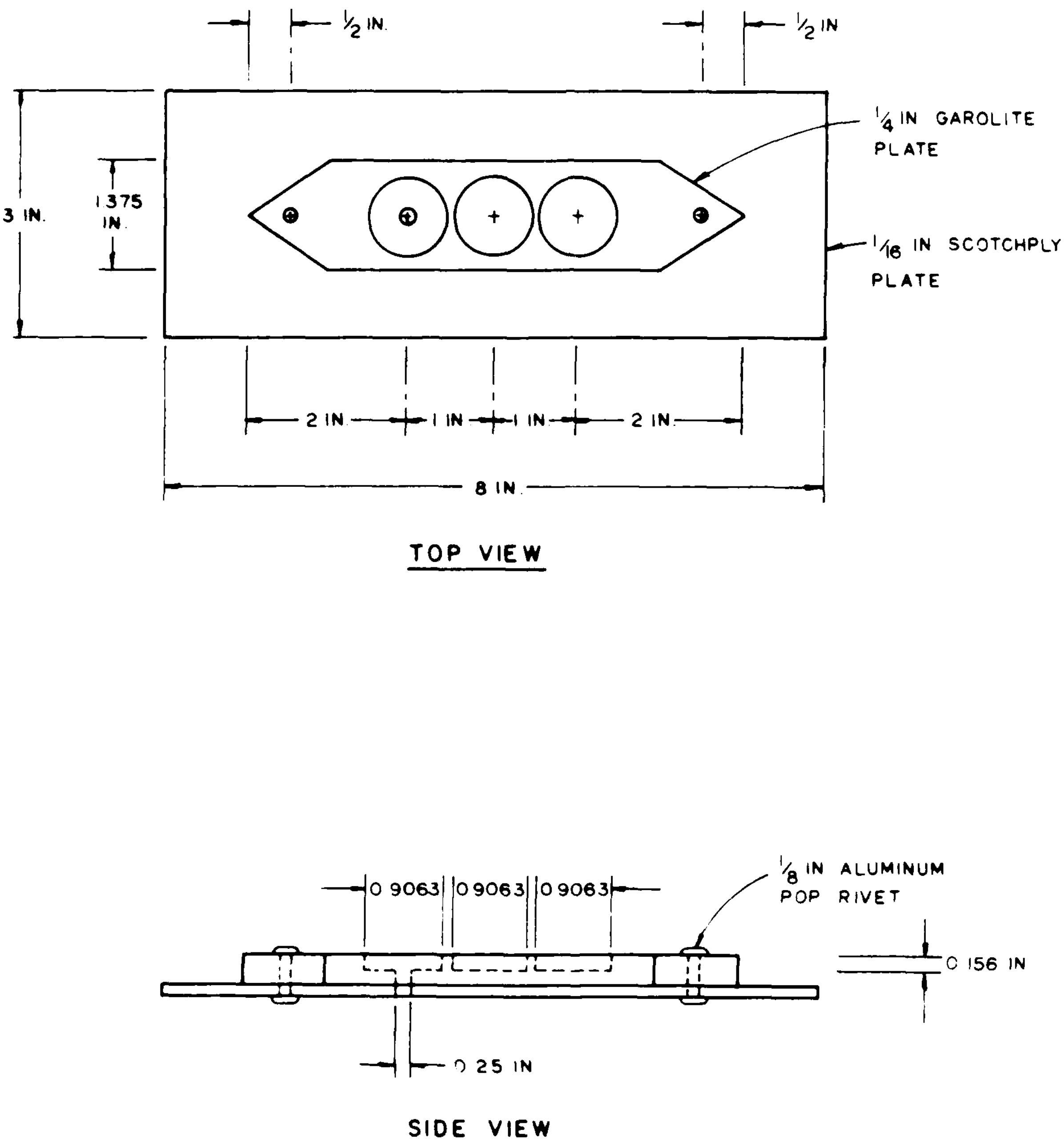


Figure A7. Take-down button assembly.

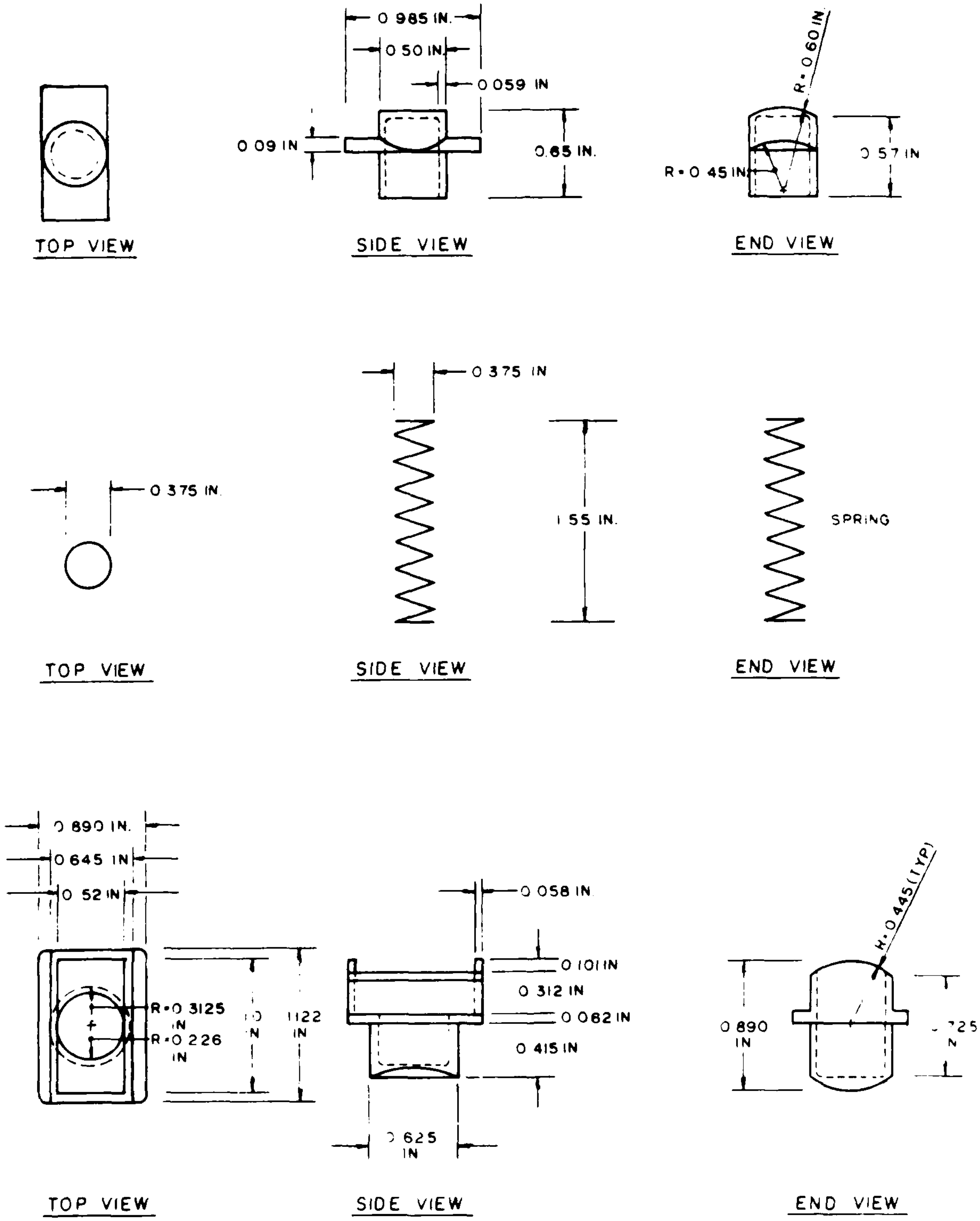


Figure A8. Triple-tube baseplate.

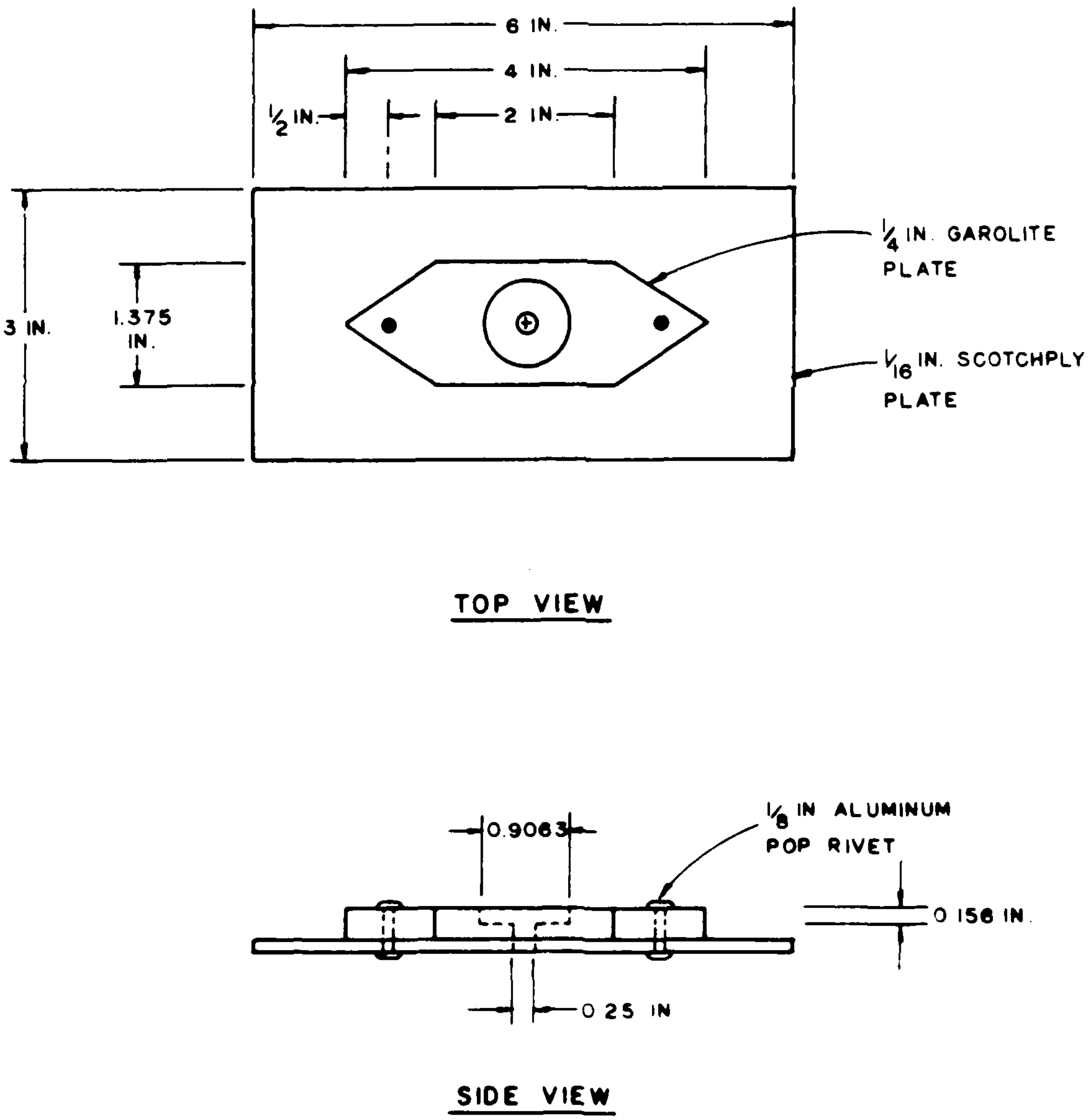


Figure A9. Single-tube baseplate.

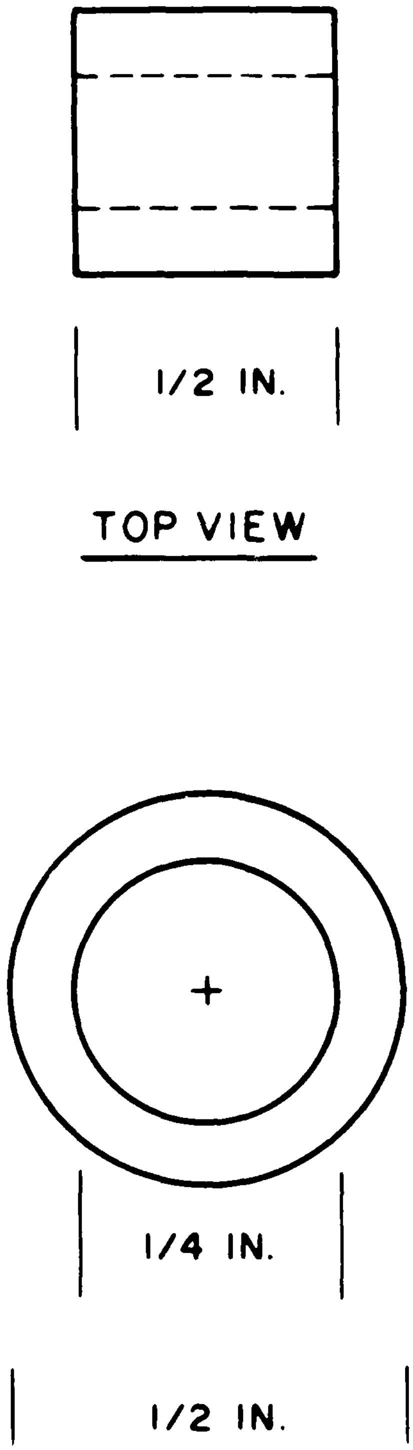


Figure A10. Elastic shock cord stop.

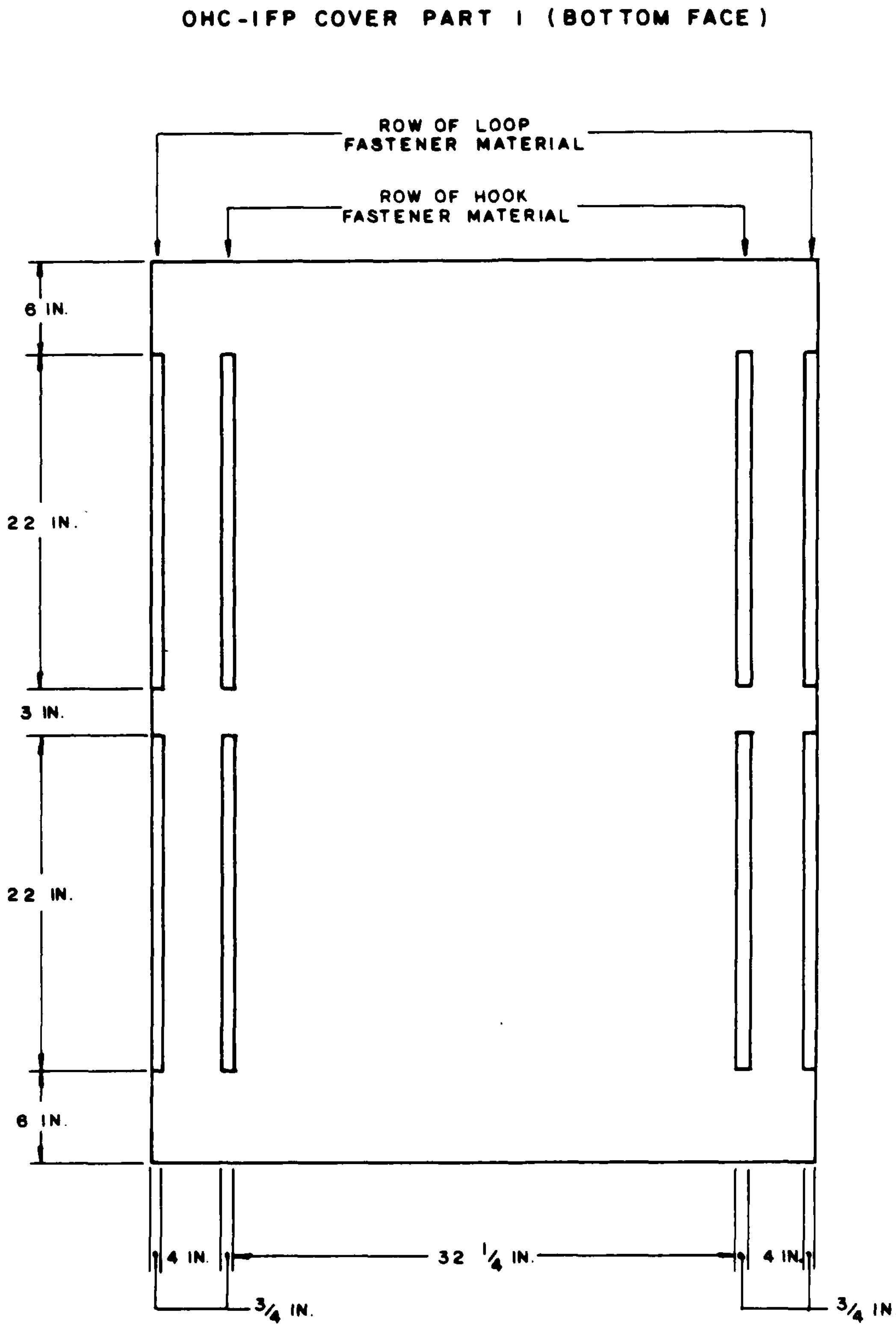


Figure A11. Main cover half bottom.

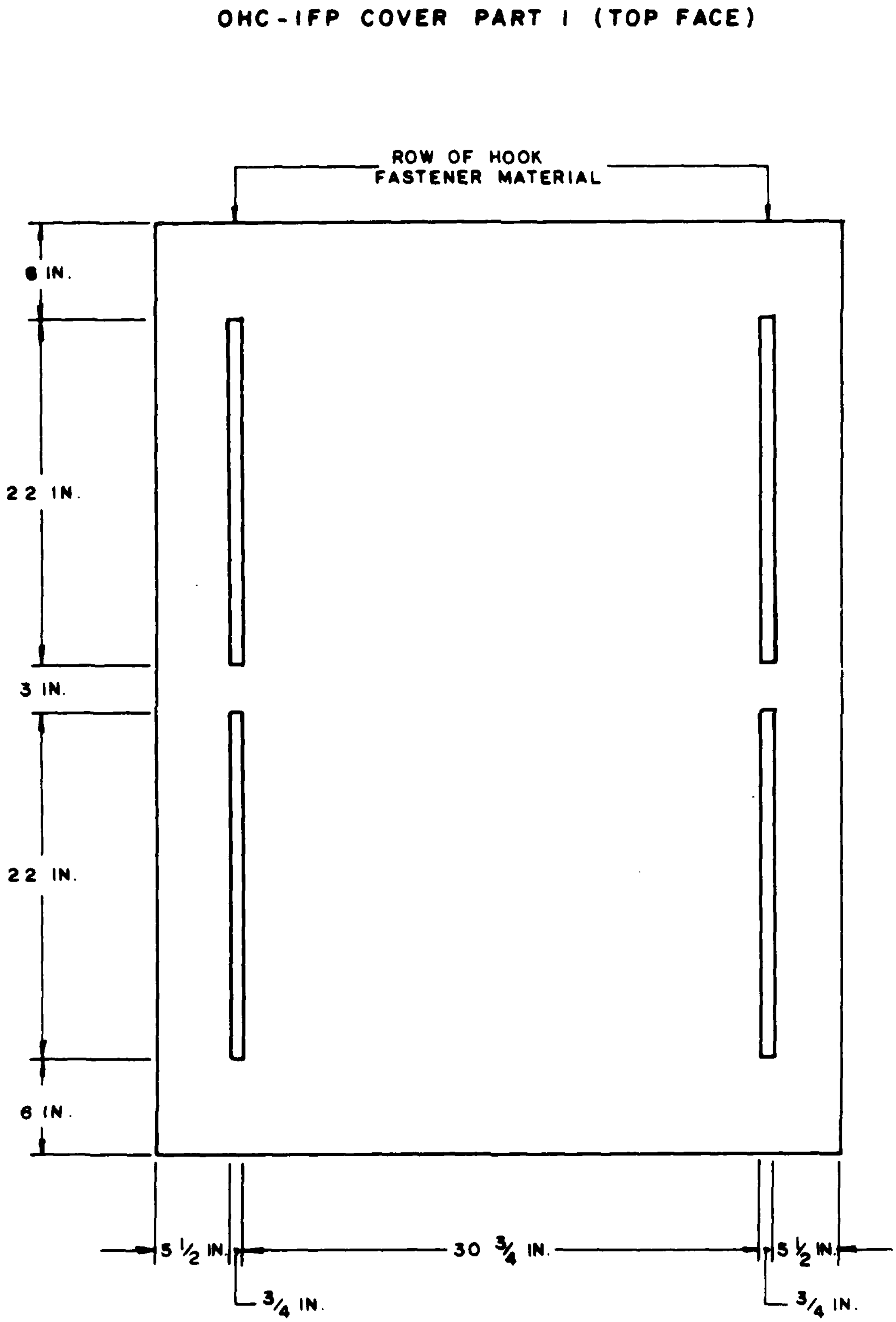


Figure A12. Main cover half top.

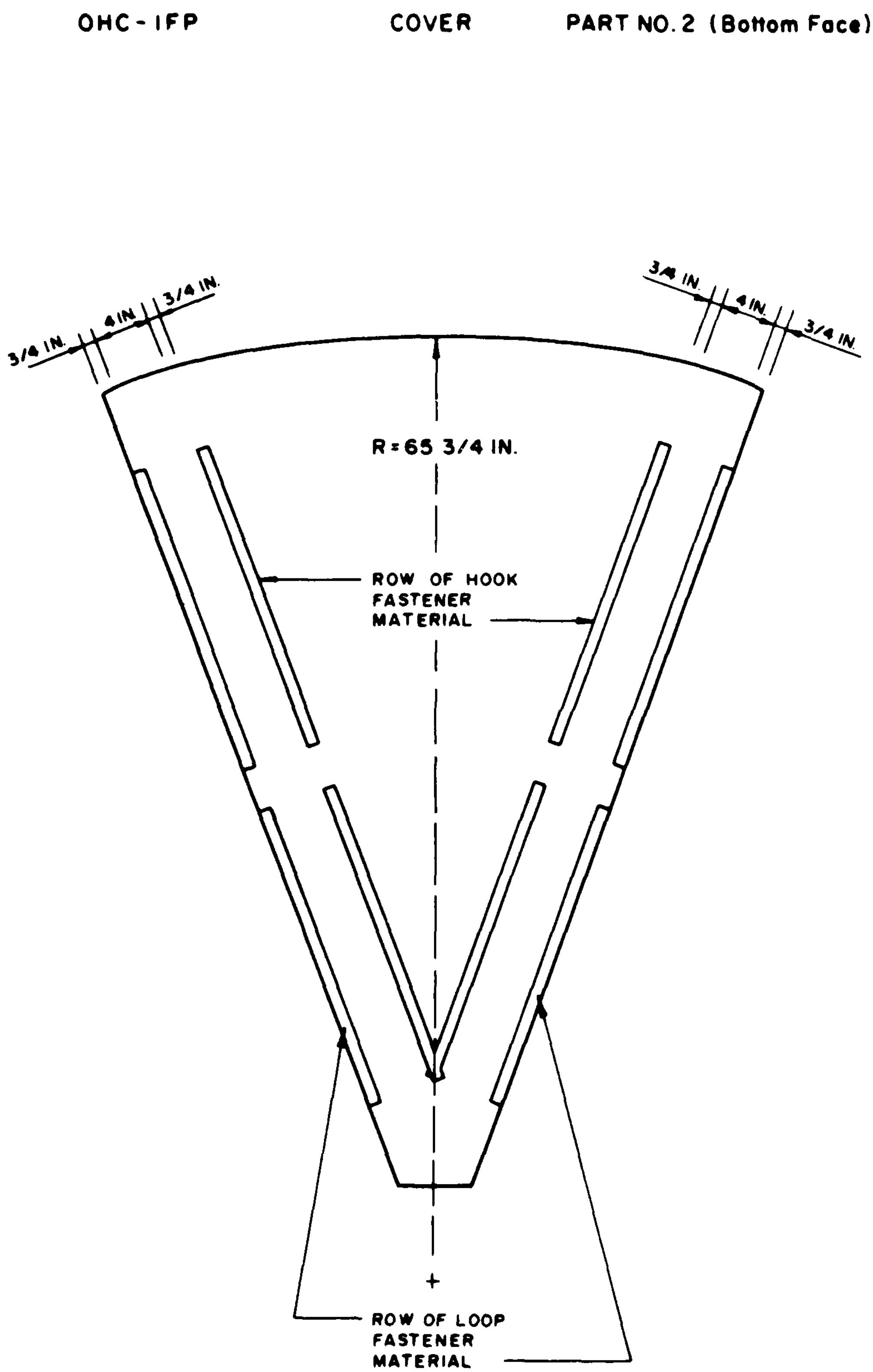


Figure A13. Firing port cover half bottom.

OHC - IFP   COVER   PART NO. 2 (Top Face)

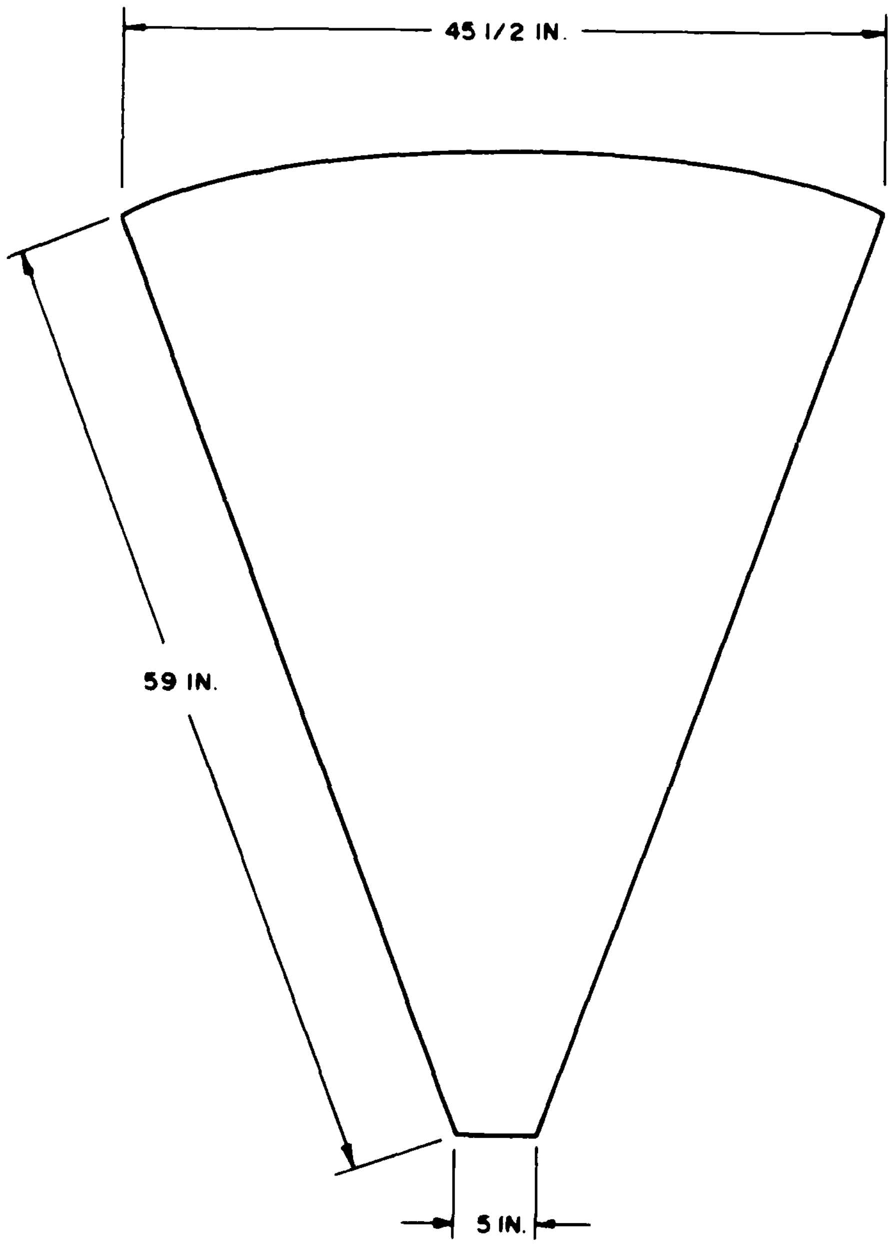


Figure A14. Firing port cover half top.

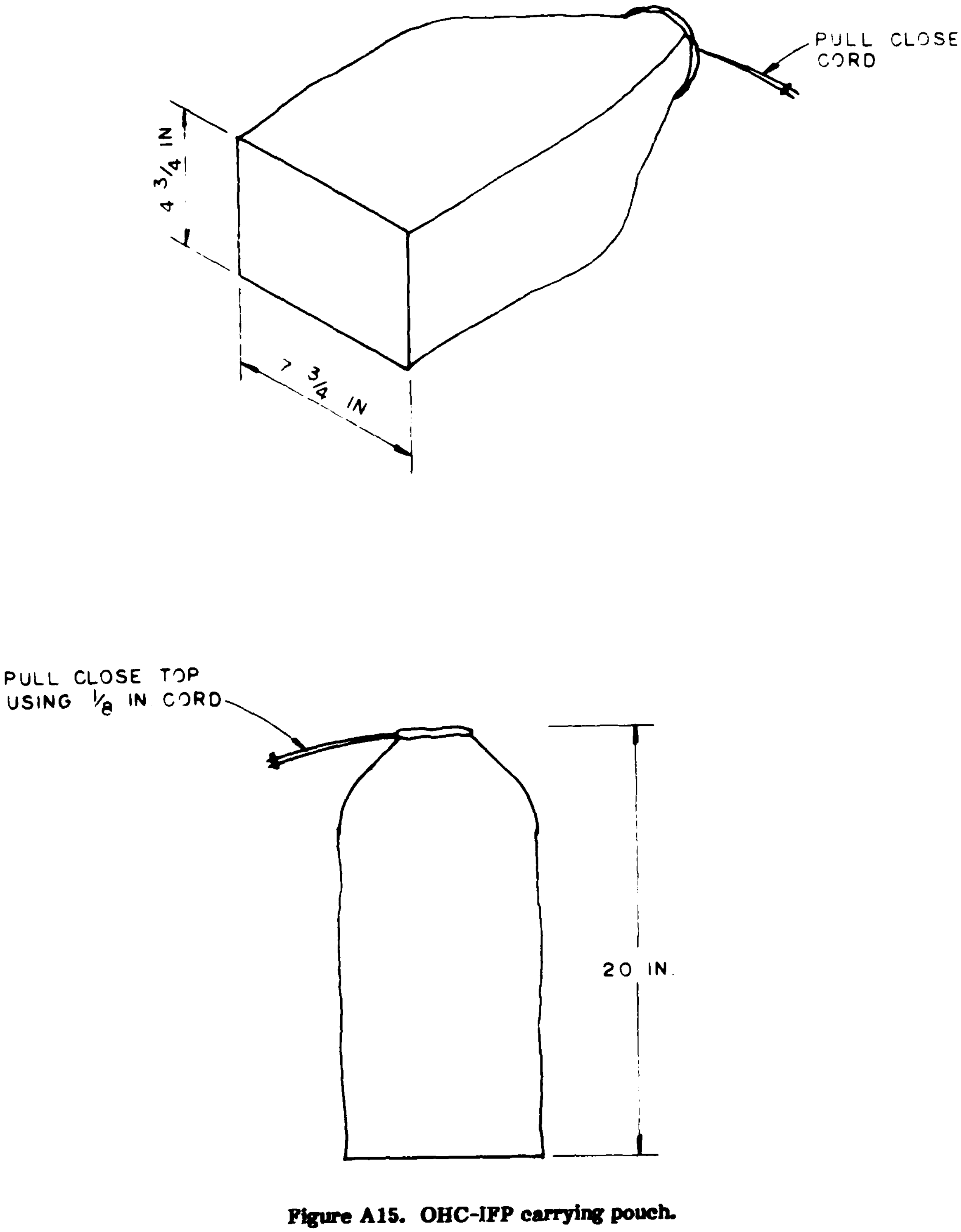
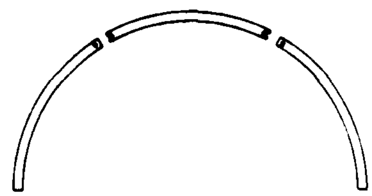


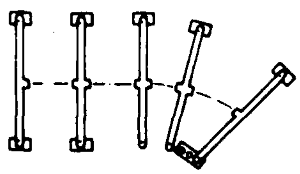
Figure A15. OHC-IFP carrying pouch.

APPENDIX B:

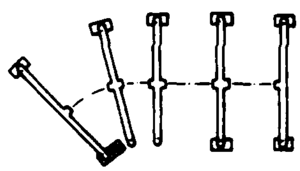
OHC-IFP ASSEMBLY PROCEDURE



-ASSEMBLE THE TUBULAR ARCH SECTIONS BY INSERTING THE ENDS OF THE SMALLER DIAMETER TUBES INTO THE LARGER TUBE SO THAT THE PIN IN THE SMALLER TUBE FULLY ENGAGES INTO THE GROOVE OF THE LARGER TUBE.

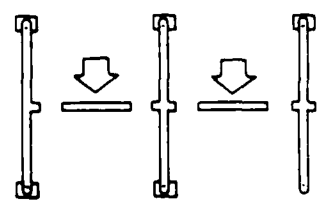


RIGHT DOG-LEG

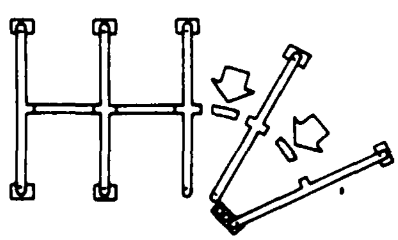


LEFT DOG-LEG

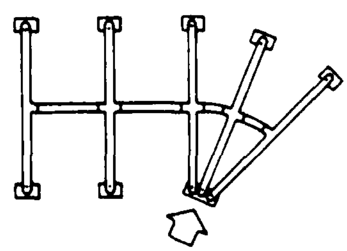
-ARRANGE ALUMINUM TUBE ARCHES AS INDICATED FOR EITHER A RIGHT DOG-LEG CONFIGURATION OR A LEFT DOG-LEG.



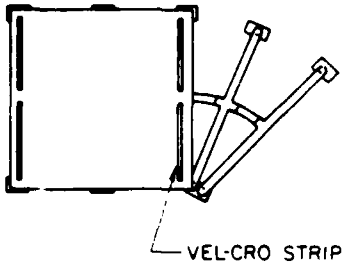
-SNAP INTO PLACE THE LONG TUBE SECTIONS ALONG THE COVER PEAK



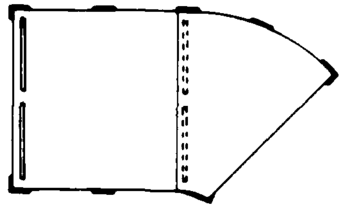
-SNAP INTO PLACE THE SHORT CURVED SECTIONS ALONG THE ALONG THE COVER PEAK.



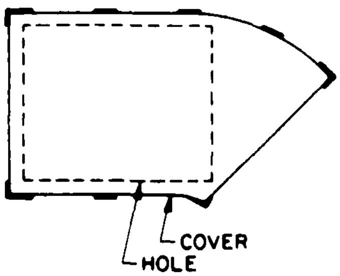
-SET THE TUBE ENDS AT THE CORNER INTO THE FOOT SOCKETS PROVIDED.



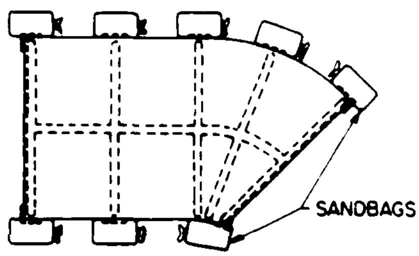
-LAY THE LARGE RECTANGULAR PIECE OF FABRIC OVER THE STRAIGHT SECTION OF THE FRAME AND SECURE IT AROUND THE ENDS USING THE VEL-CRO ATTACHMENT



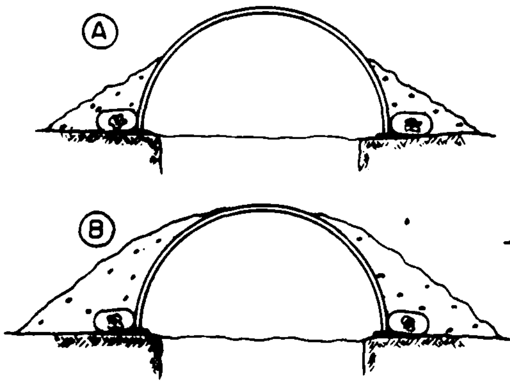
-LAY THE WEDGE SHAPED PIECE OF FABRIC COVER OVER THE REMAINING UNCOVERED PART OF THE FRAME AND SECURE IT AROUND THE END FRAME WITH THE VEL-CRO
-ATTACH THE OTHER EDGE TO THE FIRST RECTANGULAR PIECE OF FABRIC BY USING THE VEL-CRO STRIP ON TOP OF IT



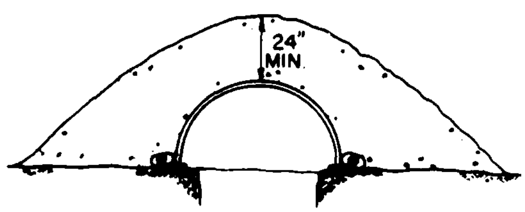
-PLACE THE ASSEMBLED COVER OVER THE FOXHOLE SO THAT THE HOLE IS CENTERED BENEATH IT.



-PLACE A SANDBAG AGAINST THE OUTSIDE OF EACH OF THE FRAME FEET.



- COVER THE ARCH WITH SOIL. MAKE SURE THAT THE SOIL IS BUILT UP ALL ALONG THE SIDES OF THE BASE FIRST, THEN BUILT-UP EVENLY TO COVER THE TOP



-COVER TO 24 INCHES OF SOIL OVERHEAD.

APPENDIX C:

STRUCTURAL ANALYSIS CALCULATIONS

The first part of this analysis was conducted assuming a top loading for the structure. Figure C1 is a schematic of this condition. Other assumptions include:

- Pinned support (thus prohibiting movement by the base of the logs while under a load)
- Soil density = 120 lb/cu ft
- Soil depth = 24 in.
- Distance between supports = 18 in.
- Each arch is rigid at the top (there is no allowable movement between support members).

Thus, to calculate the total load experienced by the structure (w):

$$w = PDd \quad [\text{Eq C1}]$$

Where:

P = soil density
D = distance between supports
d = soil depth.

From the assumptions above:

$$w = 30 \text{ lb/in.}$$

To determine the horizontal force at the base of the structure, USA-CERL used Table 18 from *Formulas for Stress and Strain*:[6]

$$H_A = LP_H/A_{HH} \qquad [\text{Eq C2}]$$

where:

$$A_{HH} = \theta + 2\theta c^2 - 3\,sc + \alpha(\theta + sc) + \beta(\theta - sc)$$

and LP_H is a loading term. In this expression, the axial stress deformation term (α) and transverse shear deformation term (β) are negligible relative to bending deformation, so they are assumed to be zero. Thus, when $s = \sin\theta$ and $c = \cos\theta$:

$$A_{HH} = 1.385$$

$$LP_H = wR[sc^2/2 - s^3/3 + \theta c/2 - \theta c^3]$$

Where $s = \sin\theta$ and $c = \cos\theta$ as above and R is the arch radius. Thus:

$$LP_H = -338.9$$

[6]R. Roark and W. Young, *Formulas for Stress and Strain* (McGraw-Hill, 1975), pp 240-243.

Therefore: $H_a = -243.6$ lb.

To find the vertical support reaction at B (V_B):[7]

$$V_B = wd = 540 \text{ lb} \qquad \text{[Eq C3]}$$

The moment at c is:

$$M_c = 682.3 \text{ lb}$$

The compressive reaction at c is:

$$C_c = H_A = -243.6 \text{ lb}$$

The cross sectional area of a tube is:

$$A = 0.1464 \text{ sq in.}$$

The section property of the aluminum shape is:

$$s = 0.0331 \text{ cu in.}$$

The stress in compression is:

$$S_c = C_c/A + M_c/s$$

$$S_c = 1664 + 20{,}612$$

$$S_c = 22{,}276 \text{ psi}$$

The allowable stress = 25,000 psi.[8] Thus, the OHC-IFP meets compressive strength requirements.

To calculate stress in tension (S_t):

$$S_t = -1664 + 20612$$

$$S_t = 18{,}948 \text{ psi}$$

The allowable stress = 24,000 psi; therefore, the structure will not fail under this loading condition.

For the second case in which 1 in. horizontal movement of the supports is allowed, Equations C1 through C3 were used again to analyze the structure with both top and side loadings. Figure C2 depicts this arrangement.

---

[7] *Engineering Data for Aluminum Structures*, 4th Ed., Construction Manual Series Section 3 (The Aluminum Association, Inc., Washington, DC, April 1982), p 43.

[8] *Specification for Aluminum Structures*, 4th Ed., Construction Manual Series Section 1 (The Aluminum Association, Inc., Washington, DC, April 1982), p 40.

$$w = 31.716 \text{ lb}$$

In this case:

$$LP_H = LP_{He} + LP_{Hf} + LP_{Hg}$$

Where $LP_{He} = LP_H$ (from equation 1e of the Roark and Young Table 18). LP_H is the same as that calculated for fixed supports above. Also, from Roark and Young's Table 18, equation 1f:

$$LP_{Hf} = LP_H$$

$$= wR\,[\theta/2\,(1 - 5c/2 + 2c^2 - 3c^3) - 3sc/2 + 11sc^2/4 + s^3/3]$$

From equation 1g (Roark and Young):

$$LP_{Hg} = LP_H$$

$$= wR\,[-\theta\,/2\,(1 + c/2 + 2c^2 - c^3) + 3sc/2 - s/4 + 7s^3/12]$$

Thus:

$$LP_H = -17.7 \text{ lb}$$

$$V_A = 540 \text{ lb}$$

$$H_A = -25.4 \text{ lb}$$

$$M_C = -508 \text{ lb}$$

$$C_C = 539 \text{ lb}$$

$$S_c = 3682 + 15{,}347 = 19{,}029 \text{ psi} < 25{,}000 \text{ psi}$$

$$S_t = -3682 + 15{,}347 = 11{,}665 \text{ psi} < 24{,}000 \text{ psi}$$

Therefore, with a 1-in. deflection outward of the arch base under load, the structure will not fail. Since the S_c and S_t values are lower than for the pinned case, the OHC-IFP is more sound structurally with the 1-in. deflection.

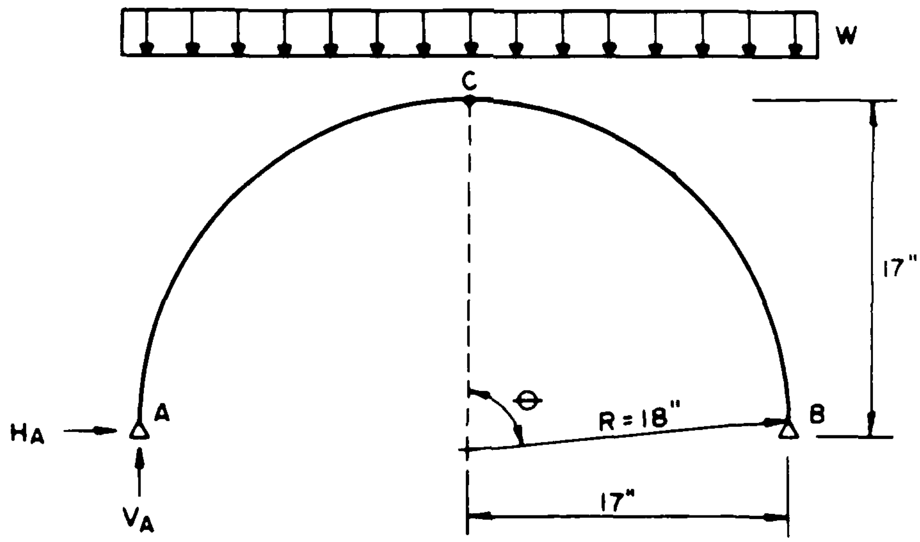


Figure C1. Structural analysis with top loading only.

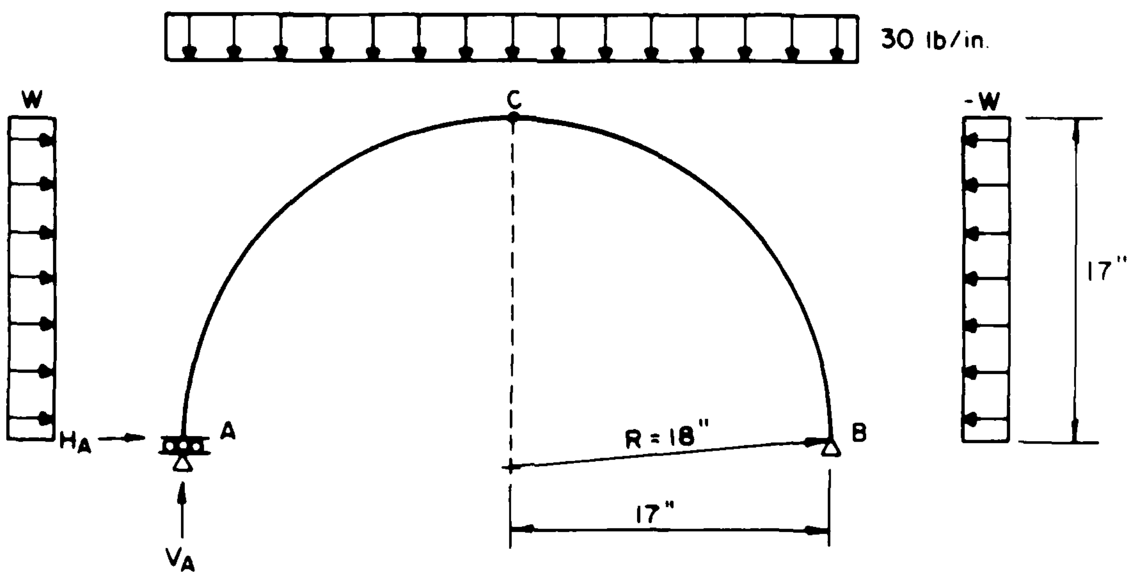


Figure C2. Structural analysis with both top and side loading.

APPENDIX D:

CUSTOMER TEST RESULTS

A customer test was conducted by ADEA during December 1986 at Fort Lewis, Washington. Soldiers from the 9th Infantry Division participated in the test, which evaluated the OHC-IFP developed by USA-CERL along with three others produced under BRDEC contracts. Tables D1 through D4 list results; the USA-CERL OHC-IFP is designated as "A" in all tables and figures.

Figure D1 shows the average emplacement times for the covers tested. Figure D2 shows the difference in assembly trials between soldiers who had never before assembled an OHC-IFP and those who had assembled other covers previously. Figure D3 graphs performance for the USA-CERL OHC-IFP.

The customer test revealed that when an OHC-IFP was placed on the Alice Pack, it interfered with the soldiers' ability to fire from a prone position. It also was determined that a 24-in.-wide foxhole is too narrow for the average soldier and that a 30- to 32-in.-wide foxhole is needed. Because of the high profile of these overhead covers (Figure D4), very few of the soldiers expressed a desire to take this style OHC-IFP into combat.

Some safety problems noted with the USA-CERL OHC-IFP include (1) two structural failures due to improper loading and (2) some minor cuts from the sharp edges on the aluminum tubing. Other problems with USA-CERL's design were:

- Missing stop pins on legs
- Failed pushbutton retainers
- Torn covers*
- Broken elastic cords in legs
- Missing instructions.

---

*Covers were torn by shovels while soldiers were digging the OHC-IFP out of the ground.

Table D1

Emplacement Times (min) for Four OHC-IFP Designs

	Type of OHC-IFP			
Conditions	A	B	C	D
Uniforms, day trials:				
Duty, no gloves	4.23	3.51	3.59	3.23
Duty, gloves/liners	5.04	4.14	4.13	3.62
Cold weather	5.20	4.36	4.74	4.52
Uniforms, night trials:				
Duty, gloves/liners	5.43	4.77	4.42	4.03

Table D2

Percentage of Soldiers Meeting the Assembly Time Criteria

	Type of OHC-IFP			
Conditions	A	B	C	D
Uniforms, day trials:				
Duty, no gloves	82.1	96.4	85.7	96.4
Duty, gloves/liners	100	100	100	100
Cold weather	100	100	100	100
Uniforms, night trials:				
Duty, gloves/liners	100	100	100	100

Table D3

OHC-IFP Cover Times (min)*

Conditions	Type of OHC-IFP			
	A	B	C	D
Day trials (gloves):				
One-man positions	35.1	23.1	24.7	22.9
Two-man positions	27.0	16.0	16.5	18.9
Night trials (gloves):				
One-man positions	17.7	13.4	12.6	14.0

*The time required to cover the OHC-IFP with dirt.

Table D4

Exit Performance Summary*

Conditions	Type of OHC-IFP			
	A	B	C	D
Avg. exit times (sec):				
One-man positions	5.4	4.9	5.5	4.7
Two-man positions	5.8	7.5	6.7	7.6
Percent meeting criterion:				
One-man positions	61.5	61.5	58.	75.7
Two-man positions	30.4	7.4	3.3	8.3

*Time required for soldiers to vacate the completed OHC-IFP.

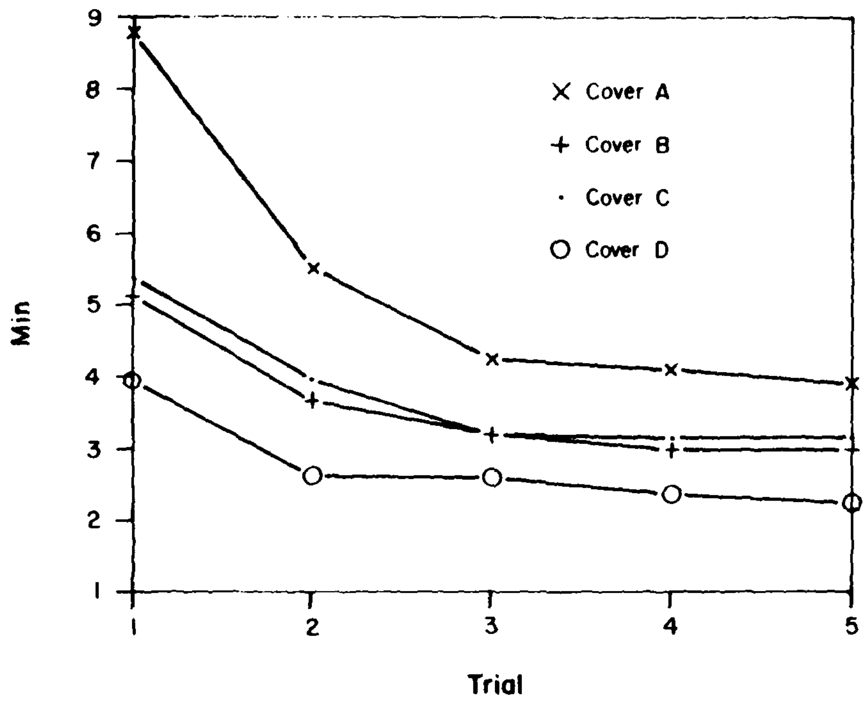


Figure D1. Emplacement times during training.

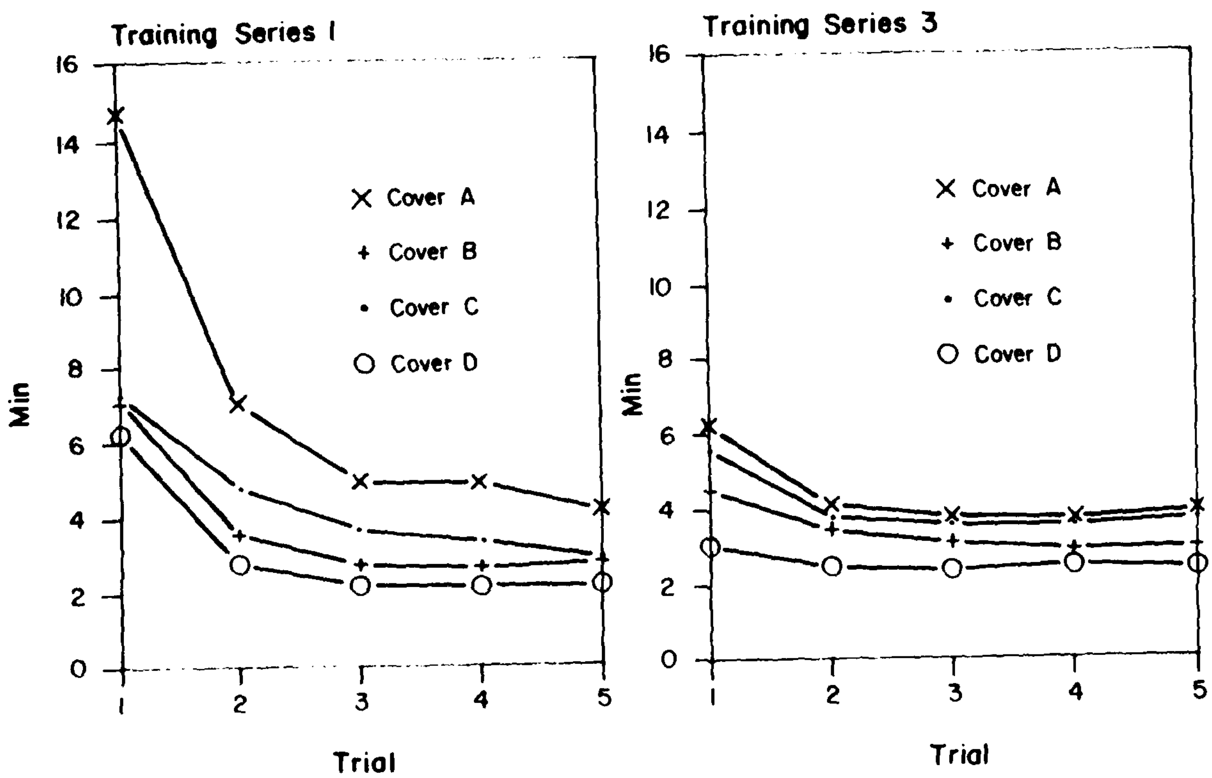


Figure D2. Learning rate differences on assembly of OHC-IFP.

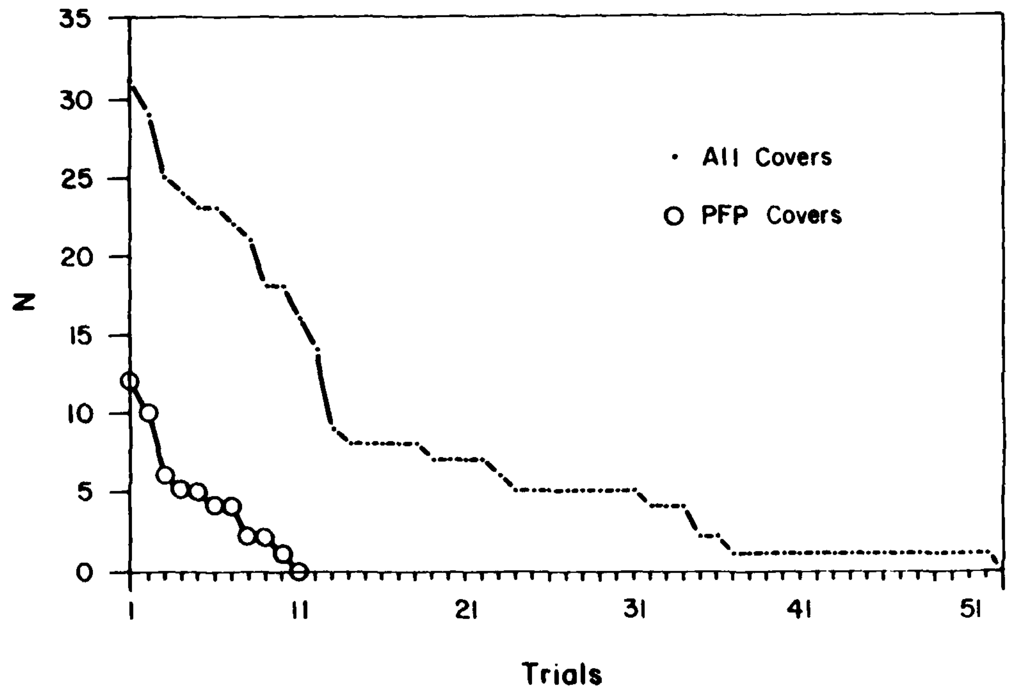


Figure D3. Covers remaining vs. trials completed.

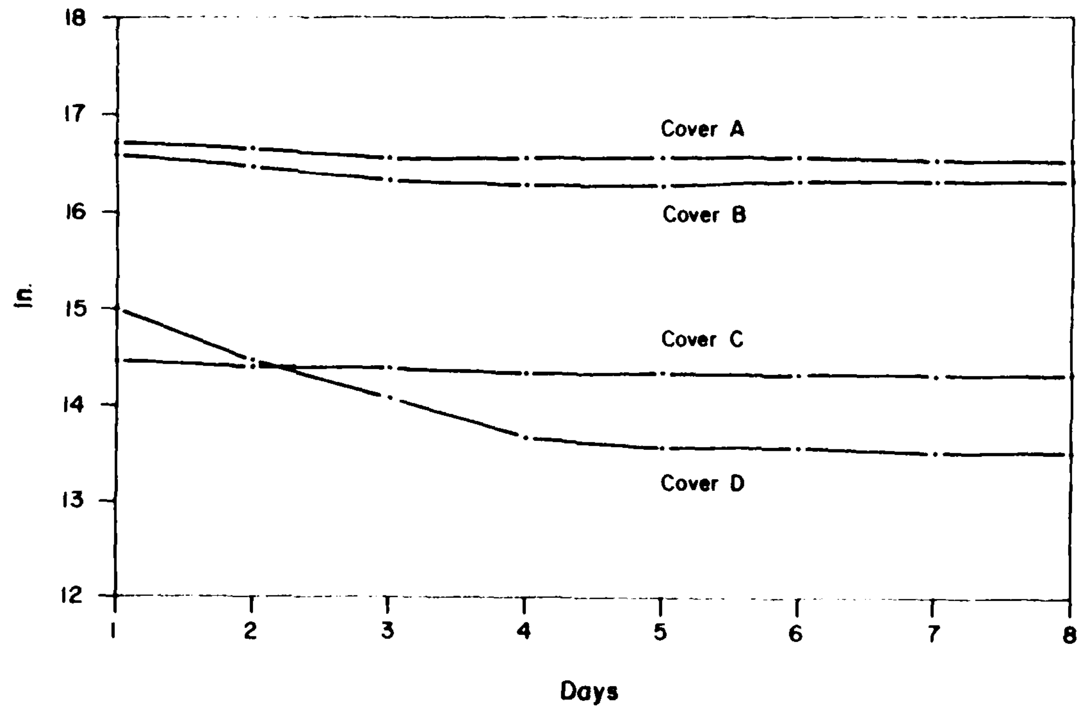


Figure D4. Centerline apex to ground distance.

MILITARY CORE DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: CEIM-SL (2)
ATTN: CECC-P
ATTN: CERD
ATTN: CERD-M
ATTN: DAEN-ZCF
ATTN: DAEN-ZCZ
ATTN: DAEN-ZCM

U.S. Army Engineer Divisions
ATTN: Library (14)

U.S. Army Schools
ATTN: Combat Developments
ATTN: Dir. of Trng and Doctrine
ATTN: Dir. Trng Development
ATTN: Engr Training Center

All Active Brigades, Groups and Battalions (62)

All Reserve Commands, Brigades, Groups, Div Battalions (43)

HQ FORSCOM 30330
HQ TRADOC ATTN: ATEN-AD 23651

Engineer Studies Center 22060

U.S. Military Academy 10996

ROK/US Combined Forces Command
ATTN: EUSA-HHC-CFC 96301

U.S. Army Europe and 7th Army
ATTN: ODCS/Engr 09403

US CEMTCOM 33608

U.S. Marine Corps
ATTN: Mobility and Logistics 22134

U.S. Army, Fort Belvoir 22060
ATTN: ATZA-DTE-EM
ATTN: Engr Library
ATTN: Canadian Liaison Officer
ATTN: British Liaison Officer
ATTN: Australian Liaison Officer
ATTN: French Liaison Officer
ATTN: German Liaison Officer

Cold Regions Research Engr Lab 03755
ATTN: Library

US Engr Topographic Lab 22060

Waterways Experiment Station
ATTN: Library 39180

Air Force Engr Servs Center 32403

Defense Technical Info. Center 22314 (2)

National Guard Bureau
ATTN: NBG-ARI 20310

Naval Civil Engr Lab
ATTN: Library 93041

U.S. Government Printing Office
Receiving/Depository (2)

U.S. Army Deployment & Employment Agency
9th Infantry Div., ATTN: MODE-FDD-CSB
Ft. Lewis, WA 98433

Belvoir Research & Development Command 22060
ATTN: BRDEC-STRBE-ICT

161
12/86

END
DATE
FILMED
5-88
DTIC